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LOS VECINOS MONITORING REPORT: AN AFFORDABLE MULTIFAMILY ZERO ENERGY NEW HOMES PROJECT

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions. PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

The *Los Vecinos Monitoring Report* is an interim report for the Affordable Multifamily Zero Energy New Homes Project**,** Contract Number 500-04-023 conducted by Global Green USA. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

California energy policy includes aggressive goals for the development and implementation of zero net energy buildings over the coming decades. The California Energy Commission's Public Interest Energy Research (PIER) Program supported the development of Zero Energy New Homes by funding selected proposals resulting from a request for proposals, released in 2004, to help construct Zero Energy New Homes as single-family or multifamily dwellings. Global Green USA, along with CTG Energetics, submitted a proposal for two affordable housing, multifamily projects to be constructed in Southern California. The Energy Commission selected Global Green as an awardee in 2005. This report reflects the energy and other monitored performance characteristics of the second multifamily project, Los Vecinos, in Chula Vista, California. (A separate report covers monitoring of the first project, Solara, in Poway, California.)

Wakefield Housing and Development Corporation developed Los Vecinos and completed construction in spring of 2009. It included numerous energy efficiency measures and solar photovoltaic systems in an effort to achieve the Zero Energy New Homes program goals. Global Green and its partners deployed a detailed monitoring and evaluation process to assess actual performance with respect to the goals, with a monitoring period from July 2009 through December 2009. The project team monitored energy use both at Los Vecinos and at a nearby community (Beyer) with similar characteristics and some above code energy efficiency measures.

Designed to be 43 percent better than 2005 Title 24 standards, Los Vecinos did attain the 25 percent modeled energy use reduction target. Direct comparison with the baseline community shows that electric utility costs were reduced on average by 62 percent when normalized by bedroom, slightly under the program goal of 70 percent. The summer peak demand of Los Vecinos apartments are well below the program goal of 1 kilowatt per unit throughout the year. In fact, the community is a net exporter of electricity at the time of the local utility peak for four of the six monitored months. These four months also happen to be the four hottest months of the entire year.

The fourth Zero Energy New Homes goal of meeting the energy-related targets with a net incremental cost of less than $5,000 per unit was not covered by the post-occupancy monitoring activities and has been addressed for Los Vecinos and the first ZENH affordable housing project, Solara, in the final project report to the Energy Commission by Global Green USA and CTG Energetics.

Keywords: Zero net energy, zero energy, photovoltaics, PV panels, energy efficiency, affordable housing, multifamily housing, monitoring and verification

Executive Summary

Introduction

The California Energy Commission has developed ambitious energy consumption reduction targets for the new home construction market over the coming decades. To explore the financial and technical feasibility and barriers to these goals, the Energy Commission developed a Zero Energy New Homes research program with the following goals: develop housing units that (1) perform 25 percent better than Title 24 (2005) standards, (2) have a 70 percent reduction in electric utility costs, (3) have a summer peak electrical demand of 1 kilowatt (kW) or less per housing unit, and (4) have an incremental capital cost, after rebates and incentives, of less than $5,000 per housing unit.

In 2005, under this program, the Energy Commission contracted with a team led by Global Green USA to develop two Zero Energy New Home affordable housing projects in cooperation with two non-profit developers. The first project, Solara, opened in the spring of 2007. Los Vecinos was completed in spring 2009 and is the subject of this report.

The project team monitored energy use for 22 of Los Vecinos' 42 apartments and 10 units of a nearby "baseline" complex, Beyer. However, Beyer incorporated energy efficiency measures that helped it exceed the 2001 Title 24 standards by 16 percent (as modeled), and as such, Beyer does not represent a minimally code-compliant project.

Purpose and Project Objectives

The monitoring and evaluation activities documented in this report were to analyze energy use at Los Vecinos to determine if the project met the Zero Energy New Homes program goals (excluding the incremental capital cost goal; the project team addresses this in the contract's final report) and understand a wide range of issues that affordable housing developers will need to consider when they design, build, and operate future very low energy or zero net energy buildings.

Project Outcomes

The Los Vecinos complex was designed and constructed to exceed the 2005 Title 24 standards by 43 percent and, therefore, the program goal of exceeding energy code by 25 percent was attained.

Based on the monitoring period analyzed in the report (June 2009 – December 2009), electricity bills for the Los Vecinos project were reduced by 62 percent when normalized by bedrooms, slightly below the program goal of 70 percent.

The average peak demand of the Los Vecinos apartments was well below the Zero Energy New Homes program goal of 1 kW[1]. For three out of six months monitored, the Los Vecinos apartments were exporting power back to the grid during the time of the San Diego Gas &

1 See pg. 38

Electric (SDG&E) peak demand periods. In fact, Los Vecinos was generating power during the single highest SDG&E peak demand period observed over the entire six-month study. This outcome suggests that the complex is helping to reduce local grid congestion during the most critical peak demand period of the year.

The average per apartment net energy consumption of Los Vecinos was almost 20 percent lower than the research team's projections. Photovoltaic (PV) system production was significantly higher than projected, which could be due to higher than average solar irradiance for the monitoring period or higher PV and inverter system efficiencies than expected. On a per-apartment basis, Los Vecinos consumed 14 percent less gross electricity than Beyer; normalized by bedroom, Los Vecinos consumed approximately 11 percent more gross electricity than Beyer. The different results between normalization methods may be due to the fact that Los Vecinos includes some one-bedroom apartments, whereas Beyer has only two-and three-bedroom units. To mitigate the effects of this as well as other differences between Los Vecinos and Beyer, however, apartments were selected at each community to provide an approximately even and representative distribution of orientation, number of exterior walls, and floor level, all factors that contribute to energy demands associated with seasonal comfort control.

Natural gas consumption at Los Vecinos was a third less than projected, likely due to the limited ability of modeling software to simulate actual, as opposed to relative, gas consumption for heating and domestic hot water. Los Vecinos's natural gas consumption was 40 percent less than Beyer's.

Overall, total net site energy consumption (natural gas and electricity) is 60 percent less at Los Vecinos compared to Beyer.

Residents at both communities are billed according to the same electric rate schedule. However, because net consumption at Los Vecinos is extremely low, minimum bill charges and other surcharges have a magnified effect on the effective cost of electricity. Specifically, although their bills are considerably lower in overall dollar amount than Beyer, Los Vecinos residents effectively pay almost twice as much for every kilowatt-hour of electricity. This significant difference in the effective cost of electricity is due primarily to a minimum bill charge of $0.17 per day that cannot be offset with net metering generation credits. This fee is triggered only when a customer's electricity cost is less than the minimum bill charge. Beyer residents' electricity costs are always above the minimum amount, and therefore, these customers never trigger the minimum bill charge.

As a complement to the monitoring activities, the project team installed eight in-unit energy feedback devices in apartments at Los Vecinos and four in-unit feedback devices at Beyer. These energy feedback devices display real-time energy data to the occupant through a computer display. Anecdotal data indicate that the devices did not have a measurable impact on consumption at Los Vecinos. At Beyer, residents with feedback actually consumed more electricity, although this difference was statistically insignificant.

Conclusions for Design and Operational Implications for Zero Energy New Homes

The project team observed up to a 600 percent difference in the gross electricity consumption between apartments at Los Vecinos. This significant variation of gross electricity consumption suggests that occupant behavior is one factor that needs to be considered when developing, designing, and operating zero energy homes. In addition, coordination among utility providers, solar installers, and property management is crucial to the operational success of multifamily zero energy housing.

The use of individual tankless water heating systems at Los Vecinos resulted in significantly less natural gas consumption than predicted by the modeling software and observed at Beyer.

The Los Vecinos project focused on achieving zero net *electricity* consumption goals. To achieve zero net *energy* designs, projects will have to either deploy all electric infrastructures with larger solar PV systems or use solar thermal hot water systems for space and water heating. However, particularly in multifamily housing, there may not be enough roof space available to accommodate net zero energy designs that consider both electricity and natural gas.

Recommendations

A number of key recommendations can be drawn from the conclusions:

- Research is needed to understand the effect of utility billing structures, feedback devices, and other strategies for influencing occupant behavior in order to cost-effectively achieve Zero Energy New Homes program goals.
- More performance data are needed over a longer monitoring window to substantiate the utility grid peak demand implications of Zero Energy New Home projects. Extended performance monitoring may facilitate a reevaluation of current incentive structures for solar PV and Zero Energy New Home projects based on their contribution to local grid congestion reduction.
- More research is needed to understand optimized net zero energy designs for affordable and multifamily housing that consider total site energy consumption, in particular limitations to achieving zero net energy based on building form, height, and density.
- Communication among property management, the utility company, and solar installers should be streamlined in order to ensure that PV installations, net-metering benefits, and low-income discounts are set up correctly for projects with multiple net-metering accounts.

Benefits to California

This project advances the understanding of the technical and policy issues surrounding Zero Energy New Homes project implementation. Zero Energy New Homes projects offer a number of potential benefits to the state:

- Decreased cost of living for income-qualified residents

- Decreased utility grid congestion from strategically sited Zero Energy New Homes developments
- Decreased total cost of electricity for rate payers due to decreased infrastructure costs that may result from future Zero Energy New Homes projects

1.0 Introduction

California energy policy has set a bold target for energy consumption reductions from new buildings, aiming for zero net energy consumption for all newly constructed residential buildings by 2020 and non-residential buildings by 2030. For the past several years, the Energy Commission has been exploring the technical, financial, and regulatory feasibility of this goal through a Zero Energy New Homes (ZENH) effort, administered by the Energy Commission's Public Interest Energy Research (PIER) Program. The ZENH program has four main performance goals: develop housing units that (1) perform 25 percent better than 2005 Title 24 energy efficiency building standards, (2) have a 70 percent reduction in electric utility costs, (3) have a summer peak electrical demand of 1 kilowatt (kW) or less per housing unit, and (4) have an incremental capital cost, after rebates and incentives, of less than $5,000 per housing unit.

Within the residential building sector, different building types and market niches face different issues when pursuing these ambitious energy targets and goals. Multifamily buildings, despite inherent environmental benefits of shared walls, smaller living spaces, and density levels that support public transit, face the challenge of having limited space for installing on-site generation technologies. And within the multifamily sector, affordable housing faces the challenge of simply securing enough funding to build much-needed units, let alone taking on the additional financial burden of pursuing zero energy strategies. While the long-term economic benefits of utility bill reduction for low-income tenants residing in zero energy affordable housing is particularly compelling, the financing and development model of affordable housing is completely different from that of market rate housing.

In order to further explore these issues and ultimately develop a business case for zero energy affordable housing, in 2005 the PIER Program awarded Global Green USA, a California-based non-profit environmental organization, a contract to develop two ZENH affordable housing projects in cooperation with two non-profit affordable housing developers. The first project, Solara, opened in the spring of 2007; a monitoring report similar to this one is forthcoming.[2] A second project, Los Vecinos, the subject of this report, opened in summer of 2009. Figure 1 shows an aerial photograph of Los Vecinos.

2 See Meacham, J. and P.Do (CTG), and T. Bardacke (Global Green USA). *Solara Monitoring Report: Affordable Multifamily Zero Energy New Homes Project*. California Energy Commission, PIER Program. Forthcoming.

Figure 1. Aerial view of Los Vecinos affordable housing complex in Chula Vista, California

Photo Credit: Wakeland Housing & Development

This report documents six months of monitoring energy use at Los Vecinos. Developed by Wakeland Housing and Development Corporation, a 12-year-old non-profit affordable housing developer, Los Vecinos is a 42-unit affordable housing complex in the city of Chula Vista in San Diego County, California. The units are spread among three stories in a fully contiguous building that also includes communal areas and the manager's office.

In addition to significant levels of energy efficiency, each apartment unit has its own individual solar photovoltaic system. Beyond energy measures, many other green building features were included in the project, including low-water use and a community greenhouse, passive and active design to promote healthy indoor air quality, recycled building materials, and ultra-low-flow indoor plumbing fixtures. The project is redevelopment of an urban infill property in close proximity to public transit, shopping, parks, schools, and other community services. Los Vecinos received a Leadership in Energy and Environmental Design (LEED) Platinum rating

from the United States Green Building Council and was named Multifamily Project of the Year by that organization in 2009.

The goal of the monitoring activities documented in this report has been to analyze Los Vecinos to determine if the energy-related ZENH goals were met with a high statistical confidence level compared to a nearby "baseline" project. The design and modeling projections of Los Vecinos have also been compared with actual performance data, along with the impacts the project has had on the local utility system.

The fourth ZENH goal of meeting the energy-related targets with a net incremental cost of less than $5,000 per unit was not covered by the post-occupancy monitoring activities. This goal is addressed comprehensively for both ZENH affordable housing projects in the final project report (which the Energy Commission will publish subsequent to this interim report).

2.0 Method

The project team has monitored a statistically significant sample of the Los Vecinos ZENH units (52 percent, or 22 units) for a period of six months, while simultaneously monitoring a sample of 10 units developed and owned by the same developer ("baseline units"). The baseline units at the apartment complex called Beyer have similar size, location, and utility providers, so that the primary differing factors between the baseline and ZENH groups are the energy efficiency upgrades and use of solar photovoltaics. An additional difference is that Beyer contains only two-and three-bedroom apartments whereas Los Vecinos also includes a number of one-bedroom apartments.

Beyer was designed and constructed to be 16 percent above Title 24 2001 standards, so the comparison to Los Vecinos does not represent an exact comparison with 2005 Title 24 code compliant construction. Because the project team monitored only 10 Beyer apartments, peak demand comparisons may not be statistically valid. However, the team gathered utility bills from Beyer to ensure statistical validity of all cost and consumption analyses.

Monitored data for each unit includes utility power consumption and photovoltaic power production. The project team collected electric and gas utility bills to corroborate the monitored electrical data and to provide overall energy consumption numbers that include natural gas. The team gathered apartment-specific data including number of bedrooms, area, and location in the building and normalized the data when comparing ZENH units with baseline units.

The data collected from each residential unit during the project are listed below:

- Utility power consumption (kW)
- AC Voltage (VAC)
- Utility Power factor (Pf)
- PV power production (kW)

The team collected data in 15-minute intervals and stored them both locally in an onsite computer and offsite in a database through an internet connection. Figure 3 shows the detailed single line wiring diagram for each apartment building, highlighting the communications network used to gather apartment power consumption and PV power production.

Additionally, the project provided The Energy Detective (TED) in-home energy monitors to a subset of residents at both communities in order to study the effect of real-time feedback on consumption and cost. Appendix A contains detailed information about TEDs and about the Dent ElitePro power meters that the project team used.

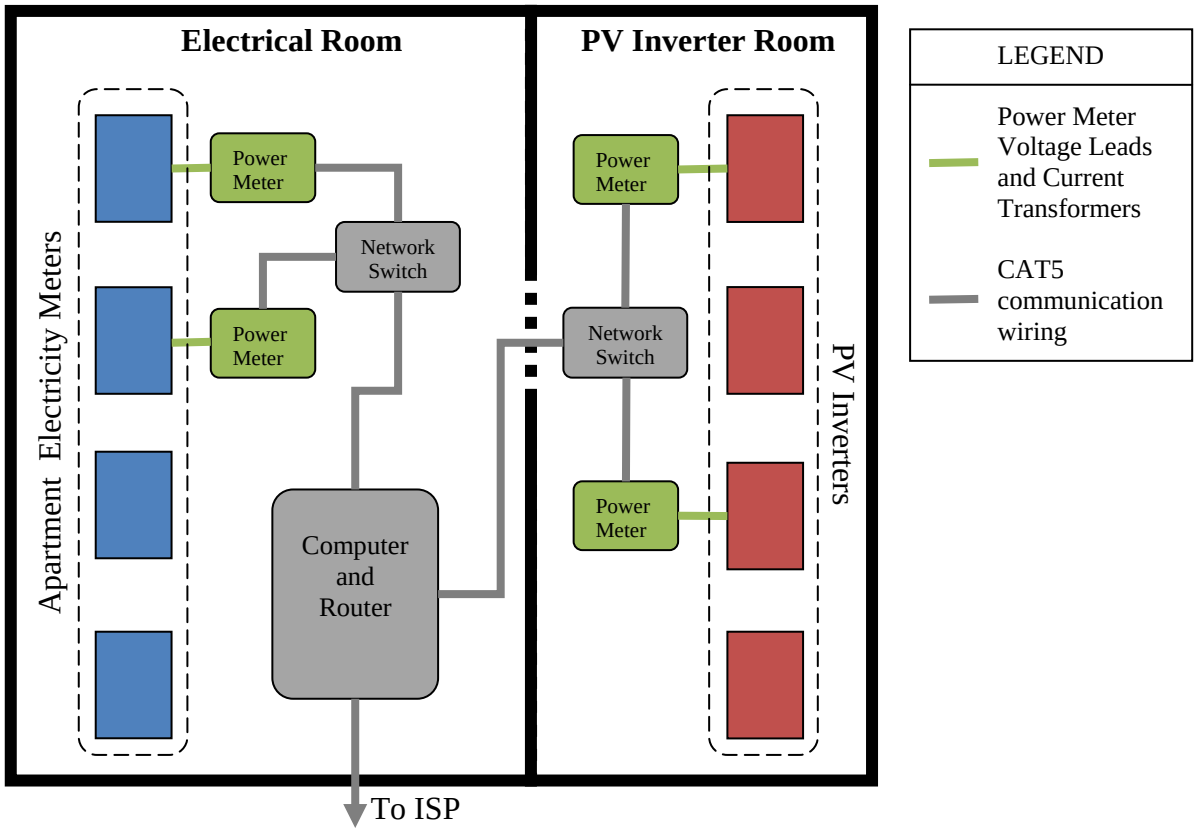


Figure 2. Single-line diagram of communications and power metering infrastructure

Source: CTG Energetics

2.1. Monitoring Equipment Performance

As a result of the storage database and exclusive use of Dent ElitePro meters, data integrity over the six month study is extremely high. Specifically, less than 1 percent of all 100,000 data points collected over the monitoring period were lost or included errors. Most of these errors were the result of monitoring start-up and minor equipment malfunctions due to power interruption or communication issues.

The main challenge in installing the monitoring equipment was confirming consistency among installed electrical systems. Upon initial deployment of the Dent meters, CTG Energetics, Inc., the monitoring and verification consultant for Global Green USA, found inconsistent labeling/wiring between electricity meters and PV inverters. These discrepancies made installation and data validation very difficult and time consuming. In fact, CTG removed 1 of the 22 monitored units from the final data analysis because its monitored consumption differed so greatly from billed values.

2.2. In-Home Energy Feedback Devices

The project team provided a number of residents at both communities with in-home energy monitors. Although a number of energy monitoring technologies are available, this study used The Energy Detective (TED) (model TED 1001). A company called Energy, Inc., produced this device for single-panel 200-amp residential service. The team chose TED because it is capable of monitoring and reporting whole-unit energy consumption/demand and can calculate projected utility costs when programmed with a rate schedule.

Figure 3. TED energy monitor display
Source: CTG Energetics

The TED does not require any additional wiring because the monitoring hardware transmits signals to the display over existing power lines. One limitation, however, of this communication methodology is that a maximum of eight TED devices can be installed in any one apartment building. That is, the TED 1001 devices transmit on one of eight frequencies, and therefore, having any more than one device on the same frequency can lead to signal interference on the power lines.

To ensure that residents received proper training on the use of the TEDs, building management provided training to all residents who received one. This training covered the operation of the TED display as well as the meaning of each main reading. The building management also developed and distributed a reference guide to each participating resident.

For more information about these devices, please see Appendix A.

3.0 Comparison of Los Vecinos and Baseline Apartments

3.1. Design Comparison

Los Vecinos and Beyer are located within three miles of each other in coastal southern San Diego County, near the San Ysidro/Tijuana border crossing between the United States and Mexico border. The same developer constructed both projects, and they have similar income demographics and unit styles and sizes. Both communities are located in California Climate Zone 7, which is the southernmost coastal region in the state. Due to its proximity to the ocean, this zone is typically very mild with warm and comfortable summer days. Occasional Santa Ana winds will introduce hot dry weather. For more information about the climate of Chula Vista and San Diego, see Attachment I.

As detailed in Table 1, the building envelope including glazing at Los Vecinos is typically better (for energy efficiency) than at Beyer, and although both communities are three-story structures, all Los Vecinos apartments are contiguously attached whereas Beyer apartments are divided among five smaller sub-buildings. Furthermore, Los Vecinos includes one-, two-, and three-bedroom apartments, but Beyer has only two-and three-bedroom residences. In all, these design differences tend to affect the demand on seasonal comfort control (i.e., ceiling fans in the summer and heating in the winter), but the project team chose certain apartments to monitor at each community in order to mitigate these dissimilarities. Specifically, team members were careful to select apartments to result in an even and representative distribution of orientation, number of exterior walls, and floor level, all factors that contribute to seasonal comfort control and energy use.

Neither Los Vecinos nor Beyer includes air conditioning equipment. Apartments at both locations are equipped with similarly aged ENERGY STAR® electric appliances (refrigerators, dish washers, and ceiling fans). Both Los Vecinos and Beyer have energy usage associated with common areas – primarily community rooms and lighting for walkways and surface parking areas – that are linked to meters separate from those of the apartments. The owner pays the bills for these meters, and because those are ancillary to living areas, the team did not monitor their energy use.

On the other hand, there are differences in installed lighting, which can significantly affect electricity usage. Both Los Vecinos and Beyer have one installed fixture in each of the kitchen, living/dining area, bathroom, and bedroom. In Los Vecinos each of these fixtures is a pin-type compact fluorescent fixture (thus ensuring that CFL lamps are used) whereas Beyer uses these high efficiency fixtures only in the kitchen.

With ENERGY STAR appliances and no air conditioning, natural gas use for heating and domestic hot water (DHW) becomes important in regard to overall energy use. Although both communities use gas-fired combined space and water heating systems, Los Vecinos uses individual tankless water heaters that are much more efficient than the individual tank-type

water heater/space heating systems at Beyer. Therefore, although installed lighting does vary, the project team expected natural gas consumption to dominate any differences in energy performance between the two communities over gross electricity use. Table 1 highlights the differences in Los Vecinos' design with respect to both 2005 Title 24 and the baseline community, Beyer.

Table 1. Differences in the design of Los Vecinos with respect to 2005 Title 24 Standards and the baseline community, Beyer

Features	Title-24 (2005) Requirements	Beyer	Los Vecinos
Number of Apartments	N/A	60	42
Number of Contiguous Buildings	N/A	5	1
Attic Insulation	R-30	R-30	R-49
Wall Insulation	R-13	R-13	R-19
Radiant Barrier	No	No	Yes
Insulation Installation Quality Inspection	No	No	Yes
Low Air Infiltration Inspection	No	No	No
Glazing (U-factor and SHGC)	0.41 U-factor 0.41 SHGC	0.60 U-factor 0.65 SHGC	0.39 U-factor 0.36 SHGC Low-E
Fixed Exterior Shading of Windows	No	Yes	No
Water Heating	Central gas-fired system with 80% recovery efficiency plus standby losses from storage tank OR individual tank-type water heaters	Individual water heaters (40 to 50 gallons) with 76% recovery efficiency using fan coil units.	Individual gas-fired tankless water heaters using fan coil units.
Aquastat[3] recirculation pump	No	No	NA

3 An aquastat is a device used to control the heating and pumping of water in hot water systems. Typically an aquastat will enable heating when the water temperature drops below a certain setpoint and will disable heating when the temperature is above a second setpoint.

Features	Title-24 (2005) Requirements	Beyer	Los Vecinos
Space Heating	80% AFUE gas-fired furnace	Fan coil units utilizing individual water heaters (40 to 50 gallons) with 76% recovery efficiency.	Fan coil units individual gas-fired tankless water heaters.
Air Conditioning efficiency	13.0 SEER	NA (Ceiling fans only)	NA (Ceiling fans only)
Duct Insulation / Location	R-4.2 for unconditioned spaces	R-4.2	R-4.2
Tight Duct	Yes (not third party tested)	No	Yes
Adequate Airflow Inspection	No	No	No
Lighting	2005 Package	Kitchen – pin-type compact fluorescent All other spaces – mixture of screw-type incandescent and compact fluorescent	All rooms have permanently installed pin-type fluorescent and compact fluorescent fixtures
Appliances	NA	ENERGY STAR Refrigerator; ENERGY STAR Dishwasher, Gas Range, and Oven; ENERGY STAR Commercial Washers and Gas Dryers located in Community Building	ENERGY STAR Refrigerator; ENERGY STAR Dishwasher, Gas Range, and Oven; ENERGY STAR Commercial Washers and Gas Dryers located in Common Area
Total PV Installed	NA	NA	94 kW DC (74 kW for units, 20 kW for common areas)
Individual PV System Sizes	NA	NA	1.6 or 1.4 kW/3 bedroom 1.4 kW/2 bedroom 1.2 kW/1 bedroom
2005 T-24 Performance	Baseline	16% better (2001 T-24)	43% better

Source: CTG Energetics

4.0 Discussion of Data Analysis

4.1. Six-Month Monitoring Period

Although this study covers only July to December of 2009, the observations and conclusions derived from the six-month data set are indicative of annual performance. Specifically, analysis of WYEC2[4] climate data indicates that the timeframe of this study includes a representative sample of pertinent annual weather conditions. Of these conditions, solar radiation is of utmost importance in the performance of the PV arrays at Los Vecinos. As seen in Figure 4, global solar radiation[5] is highly symmetric between the months of June and July. In fact, the total average solar radiation during the six-month monitoring period is less than 5 percent lower than the balance of the year. If anything, therefore, PV performance observed in this study will be slightly conservative compared to expected annual results. On the other hand, because 72 percent of the study was conducted during daylight savings time, electricity consumption due to lighting may be higher for the balance of the year.

Furthermore, average monthly temperatures during the study are approximately 9 percent higher than the remainder of the year. Because neither of the communities has installed cooling, however, electricity consumption, which is the main focus of this study, should not be heavily impacted by the temperature disparity.

4 Weather Year for Energy Calculations 2 (WYEC2) is a standard dataset of hourly weather data used for energy modeling. WYEC2 data covers 77 locations in North America and is distributed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers.

5 Global solar radiation is a measure short-wave radiation (i.e. UV up to "near" infrared) resulting from both direct and indirect (diffuse) radiation from the sky.

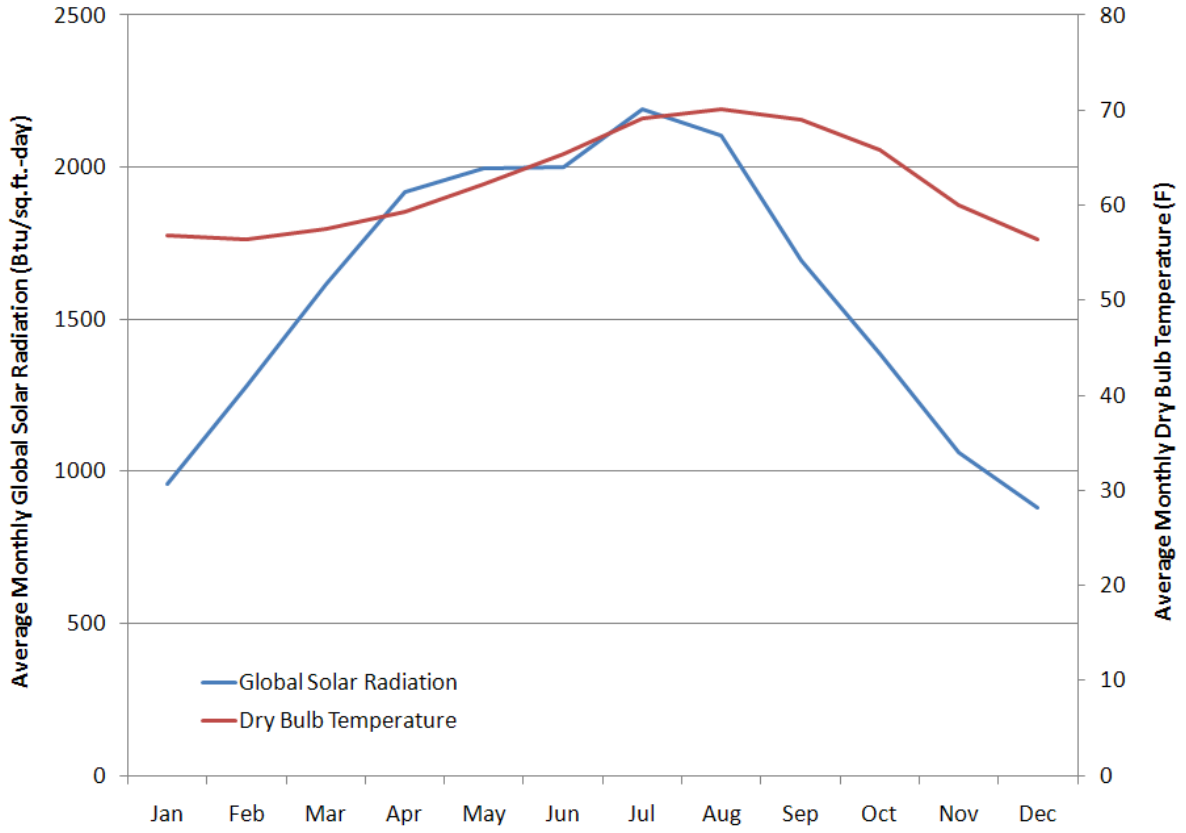


Figure 4. Average solar radiation and dry bulb temperature in California Climate Zone 7

Source: CTG Energetics

4.2. Normalization of Data

Because the monitored baseline apartments (Beyer) are on average 16 percent larger in square footage and do not include one-bedroom units, energy use comparisons based on simple per-apartment averaging tend to favor Los Vecinos. Therefore, this report provides ZENH goal performance calculations in two forms: averaged by number of apartments and normalized by number of bedrooms. Because occupancy rates across affordable housing projects are standardized by number of bedrooms, normalizations based on the number of bedrooms can be used as a proxy for occupancy normalizations which are not specifically provided in this report. In calculating average values, this report focuses solely on total project averages that provide a community-wide characterization of energy usage. For example, the "Average Cost per Bedroom" is calculated by dividing the total utility costs for all the monitored apartments by the total number of bedrooms.

4.3. Sources of Data

The project team based results for the six-month monitoring period on the data sets summarized in Table 2. In general, the team gathered data for each type of analysis from power monitoring, utility bills, and calculated values. However, this study presents only the most reliable and complete data sets for each type of analysis.

For example, although electricity consumption and cost at Beyer are available using monitored data and calculated cost, the team included utility bill information because it is consistent with the monitored and calculated data and, and it allows for an almost threefold expansion of the data set. Furthermore, screening of the 34 utility bills obtained eliminated 9 due to incomplete or missing data.

Table 2. Datasets used for each category of analysis

Community	Energy Type	Type of Analysis	Source of Data	Number of Samples
Los Vecinos	Electricity	Consumption	Power Monitoring	21
		Cost	Calculated	21
		Demand	Power Monitoring	21
	Gas	Consumption	Utility Bills	33
		Cost	Utility Bills	33
Beyer	Electricity	Consumption	Utility Bills	25
		Cost	Utility Bills	25
		Demand	Power Monitoring	10
	Gas	Consumption	Utility Bills	25
		Cost	Utility Bills	25

Source: CTG Energetics

Of particular note are the sources of data for electricity at Los Vecinos. Ideally, consumption and cost would be based on utility bills in order to allow a larger number of samples. However, a significant number of Los Vecinos residents had not been properly set up for net metering at

the time of utility bill data collection. As a result, the billed data provide inaccurate representations of actual electricity use, generation, and cost. Therefore, although the data set from utility bills is larger, consumption and cost results are respectively based on power monitoring and cost models.

5.0 Results

This report analyzes the performance of the Los Vecinos community in relation to three of the four California Energy Commission's Zero Energy New Homes (ZENH) program goals: develop housing units that (1) perform 25 percent better than 2005 Title 24 standards, (2) have a 70 percent reduction in electric utility costs, and (3) have a summer peak demand[6] of 1 kW or less.

In this study, Los Vecinos is compared to a baseline community, Beyer, which has no PV. At Los Vecinos, the project team monitored 22 apartments for both electricity consumption and PV generation and obtained utility bills for the majority of these units for verification of monitoring accuracy and energy cost information. This report excludes data from one of the monitored apartments because of large discrepancies with utility data. At Beyer, the team monitored 10 apartments and obtained utility bills for 25 apartments. Of the 25 apartments for which utility bills were obtained, seven of them were among the set of directly monitored units.

As shown in Table 3, for the six-month monitoring period from June 23 to December 21, 2009, Los Vecinos meets the ZENH cost reduction goal of 70 percent while significantly performing under the peak demand maximum of 1 kW. While Title 24 energy performance cannot be directly compared with monitored data,[7] this report compares monitored data with modeled data in Section 5.2.

6 Summer peak demand is defined as average power draw of the project across four hours surrounding the utility's maximum hour power draw. This analysis is to take place for the day with the highest power draw within the hottest month of the year.

7 Title 24 performance cannot be directly compared with monitored data because compliance models do not account for loads from plugs, some lighting, and other electricity end uses.

Table 3. Summary of project performance with respect to ZENH program goals

	ZENH Goal	Los Vecinos Performance	
		Modeled	Monitored Performance
1. Title 24 Energy Performance Better than Code[7]	25%	43.1%	NA
2a. Electricity Cost Reduction (*Per Apartment*)	70%	85%	70%
2b. Electricity Cost Reduction (*Normalized per SF*)			62%
3. Per Apartment Summer Peak Demand (kW)	1 kW	NA[8]	-0.30 kW

Source: CTG Energetics

8 Summer peak demand performance cannot be evaluated for modeled performance due to lack of consistency between utility peak timing and weather data in the simulation environment. That is, energy modeling is based on standard, prescribed temperature values, whereas utility peak timing is influenced significantly by actual local weather conditions. Modeling data did show that it was highly likely that enough PV was installed to lower peak demand below the ZENH threshold.

6.0 Energy Efficiency Evaluation

Los Vecinos was originally designed to exceed Title 24 2005 standards by 43 percent. Although actual performance with respect to Title 24 can be inferred through comparison with modeled data, compliance modeling does not account for energy from typical end uses such as plug-in lighting, other plug loads, and certain appliances. On the other hand, even though Los Vecinos apartments have no air conditioning, Title 24 residential compliance does require modeling of space cooling systems. In all, these factors complicate direct comparison of modeled and actual energy performance.

As a result, the project team performed additional calculations to estimate energy/cost performance and inform PV system sizing. To reduce the cost and effort in designing Zero Net Energy Housing, it would be helpful for residential Title 24 modeling software to include estimates of all electricity loads in a typical residential setting.

The comparison of modeled performance to observed performance for the entire six-month monitoring period is shown in Table 4. The data suggest that both observed gross and net consumptions are significantly lower than expected. The project team theorizes that this result is largely due to underestimating PV performance during modeling and overestimating loads not accounted for in Title 24 compliance modeling.

Table 4. Comparison of entire six-month modeled and observed data at Los Vecinos (22 units)

Category	Modeled	Observed	Variation in Observed Performance vs. Modeled
Gross Electricity Consumption (kWh/apartment)	1243	1043	19%
PV Production (kWh/apartment)	970	1114	13%
Electricity Cost ($/apartment)	$31.02	$39.65	22%
Natural Gas Consumption (therms/apt)	50.1	44.9	11%

Source: CTG Energetics

Natural gas consumption was also significantly lower than predicted in the energy models. This could be due to differences in hot water consumption assumptions in the Title 24 energy modeling rule set and potentially inaccurate heating assumptions in the rule set for hydronic heating applications.

6.1. Energy Cost and Usage Evaluation

6.1.1. Electricity

When compared to the baseline apartments, as shown in Table 5 and Table 6, net electricity costs and consumption for the Los Vecinos apartments are significantly less for the six-month period. Note that the difference in cost is less prominent when normalized by bedroom. The gross usage and cost indicate that the electricity usage at Los Vecinos is actually higher than at Beyer when PV production is not considered.

Table 5. Comparison of electricity costs over six months

	Los Vecinos		Beyer (Baseline)	Reduction From Baseline	
	Net (with PV)	Gross (without PV)		Net (with PV)	Gross (without PV)
Average Utility Cost – *per Apt*	$39.65	$113.72	$134.13	70%	15%
Average Energy Cost Intensity – *per Bedroom*	$19.36	$55.54	$50.81	62%	-9%

Source: CTG Energetics

Table 6. Comparison of net and gross total energy consumption over six months

	Los Vecinos (kWh)		Beyer (Baseline) (kWh)	Reduction from Baseline	
	Net (with PV)	Gross (without PV)		Net (with PV)	Gross (without PV)
Average Consumption - *per Apt*	-70.7	1043.1	1209.4	106%	14%
Average Energy Usage Intensity - *per Bedroom*	-34.5	509.4	458.1	108%	-11%

Source: CTG Energetics

A breakdown of all units' six month net energy consumption is shown in Figure 5 for comparison. For the monitoring period, 16 of 21 Los Vecinos units were net exporters to the grid, and on average, PV production covered over 130 percent of the total electricity consumption of the units, as shown in Table 7.

As seen in Table 7 and Figure 6, the PV production for each unit is relatively consistent, but the consumption of each unit varies widely. Specifically, the coefficient of variation of gross consumption[9] (kWh) is 0.52, more than seven times that of PV production (kWh per kW DC installed), which has a coefficient of variation of 0.07. Furthermore, the individual gross consumption per bedroom ranges anywhere from 328 to 2397 kWh, which represents almost an

9 Coefficient of variation (CV) is a dimensionless measure of the dispersion associated with a set of data. This metric is defined as the standard deviation of the data set divided by the mean of the data set. Therefore, a data set with a larger amount of dispersion is characterized by a higher CV.

order of magnitude variation. This suggests that occupant behavior has a significant impact on energy use and cost in zero energy apartments.

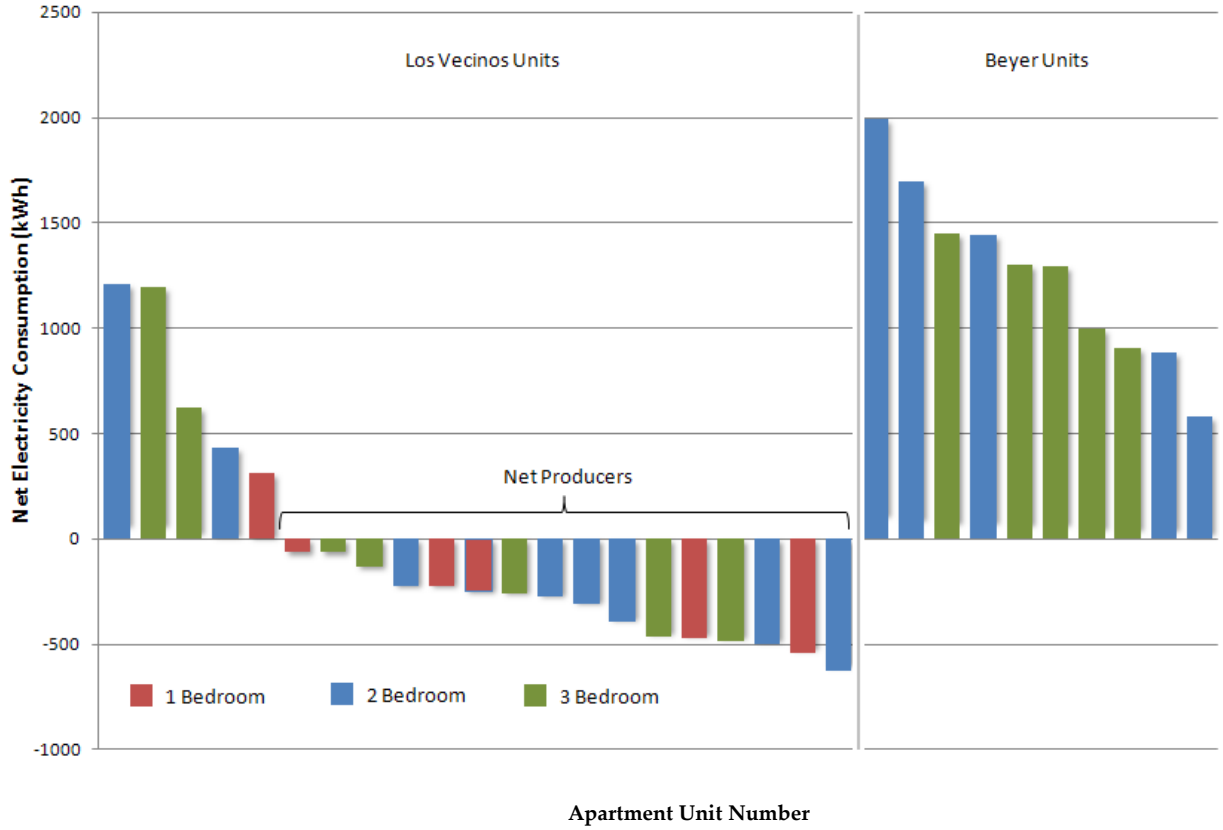


Figure 5. Net six-month energy consumption for Los Vecinos (PV included) and Beyer apartments

Source: CTG Energetics

Table 7 shows the performance of each individual apartment monitored during the project. While in general the PV system size follows the number of bedrooms (that is, the largest PV systems are on 3 bedroom units and the smallest are on 1 bedroom units), there are inconsistencies with PV system size per apartment due to space constraints of the roof and carports.

Table 7. Summary of Los Vecinos apartment attributes, electricity consumption, and PV production

Los Vecinos Apartment Number	Floor Area (sq.ft.)	PV System Size (W)	Number of Bedrooms	July to December 2009			
				Net kWh Consumption (Monitored)	PV Production (kWh)	Gross kWh Electricity Consumption (w/o PV)	PV Production as % of Total Consumption
105	1030	1600	3	-484.0	1349.0	865.0	156%
205	1030	1600	3	-258.8	1191.8	933.0	128%
210	1019	1600	3	621.2	1173.4	1794.6	65%
216	1019	1600	3	-130.4	1105.3	974.9	113%
316	1019	1600	3	-60.8	1364.4	1303.6	105%
107	1065	1400	3	1196.9	991.0	2187.9	45%
108	1020	1400	3	-462.2	1180.7	718.6	164%
110	807	1400	2	-276.2	1176.3	900.1	131%
208	807	1400	2	-300.8	1177.9	877.0	134%
209	807	1400	2	-224.3	1189.7	965.4	123%
211	807	1400	2	-623.2	950.7	327.5	290%
212	807	1400	2	1210.4	1186.0	2396.4	49%
311	807	1400	2	-396.8	1166.1	769.3	152%
313	807	1400	2	-501.5	1156.4	654.9	177%
314	807	1400	2	436.1	1162.7	1598.8	73%
102	655	1200	1	312.0	977.0	1289.0	76%
103	655	1200	1	-59.9	933.5	873.6	107%
202	654	1200	1	-242.7	952.3	709.6	134%
203	654	1200	1	-468.8	987.9	519.1	190%
302	654	1200	1	-226.9	1011.0	784.1	129%
303	654	1200	1	-543.9	1007.8	463.9	217%
Average	837	1390	2.0	-70.7	1113.9	1043.1	131%

Source: CTG Energetics

Figure 6. Six-month PV production and gross electricity consumption for monitored Los Vecinos apartments

Source: CTG Energetics

6.1.2. Effect of Energy Feedback on Electricity Consumption

Although results of the energy feedback study are not statistically significant, residents with TED devices tend to use the same amount of electricity, if not more, than residents without energy feedback. In general, the project team expected that residents with energy feedback devices would use less electricity. As seen in Table 8, however, monthly electricity consumption of residents at both communities is typically comparable or slightly higher (i.e., have a negative reduction) in apartments with TEDs. After six months, the residents at Beyer with TEDs had consumed 14 percent more electricity per bedroom. Both sets of residents at Los Vecinos ended up consuming about the same amount of electricity.

A t-test[10] of the monthly data, however, indicates that the monthly differences in energy consumption per bedroom are not statistically significant. Specifically, the sample size of the study and the difference in consumption is too small while the deviation in consumption within each group is too large.

Table 8. Energy consumption for residents with and without energy feedback devices (TEDs)

Month	Los Vecinos Average Consumption (kWh/Bdrm)			Beyer Average Consumption (kWh/Bdrm)		
	With TEDs	Without TEDs	% Change w/ TEDs	With TED	Without TED	% Change w/ TEDs
Jul	76.8	73.5	-5%	88.6	68.4	-30%
Aug	86.7	84.3	-3%	84.4	74.8	-13%
Sep	99.3	93.7	-6%	89.7	74.2	-21%
Oct	85.1	78.5	-8%	75.8	70.6	-7%
Nov	84.7	80.1	-6%	83.7	76.8	-9%
Dec	78.8	97.7	19%	81.8	78.0	-5%
Total	511.4	507.7	-1%	504.0	442.8	-14%

Source: CTG Energetics

10 A t-test assesses whether the means of two groups are statistically different from each other.

6.1.3. Natural Gas

Both communities use natural gas to heat water for space heating and domestic use. Los Vecinos uses individual tankless water heaters for both domestic hot water and hydronic space heating whereas Beyer has individual combined hot water and space heating systems using traditional storage tank water heaters. Both communities also use gas ranges and ovens. As shown in Table 9 and Figure 7, natural gas usage at Los Vecinos is significantly lower than at Beyer.

Table 9. Natural gas usage and cost comparison

Month	Natural Gas Usage (Therms per Bedroom)			Natural Gas Cost ($ per Bedroom)		
	Los Vecinos	Beyer	Percent Lower at Los Vecinos	Los Vecinos	Beyer	Percent Lower at Los Vecinos
July	3.1	5.6	45%	$2.69	$4.60	42%
August	3.1	5.3	41%	$2.81	$4.45	37%
September	2.8	4.9	42%	$2.35	$3.79	38%
October	3.1	5.7	47%	$2.67	$4.83	45%
November	4.1	7.0	42%	$3.87	$6.16	37%
December	5.6	7.9	29%	$5.46	$7.07	23%
Total	21.8	36.5	40%	$19.84	$30.89	36%

Source: CTG Energetics

The difference in gas consumption between Los Vecinos and Beyer is likely from highly efficient domestic water heating at Los Vecinos. From July to December, the trends in gas consumption at both communities track each other fairly closely. Stove size is similar at the two apartment complexes, and natural gas use for cooking likely tracks closely as well. Because most of the months studied had mild climates, the lower gas use at Los Vecinos is not likely due to space heating energy. The project team attributed Los Vecinos's lower gas consumption to domestic water heating, the only remaining end use of gas. These results are consistent with the energy model, which predicted that the majority of gas consumption would be for domestic water heating.

The percent savings in gas costs at Los Vecinos is slightly lower than in usage because Los Vecinos residents are enrolled in the utility's discount rate program, California Alternate Rates for Energy (CARE). The effects of CARE enrollment in utility natural gas programs are discussed in Section 6.1.5.

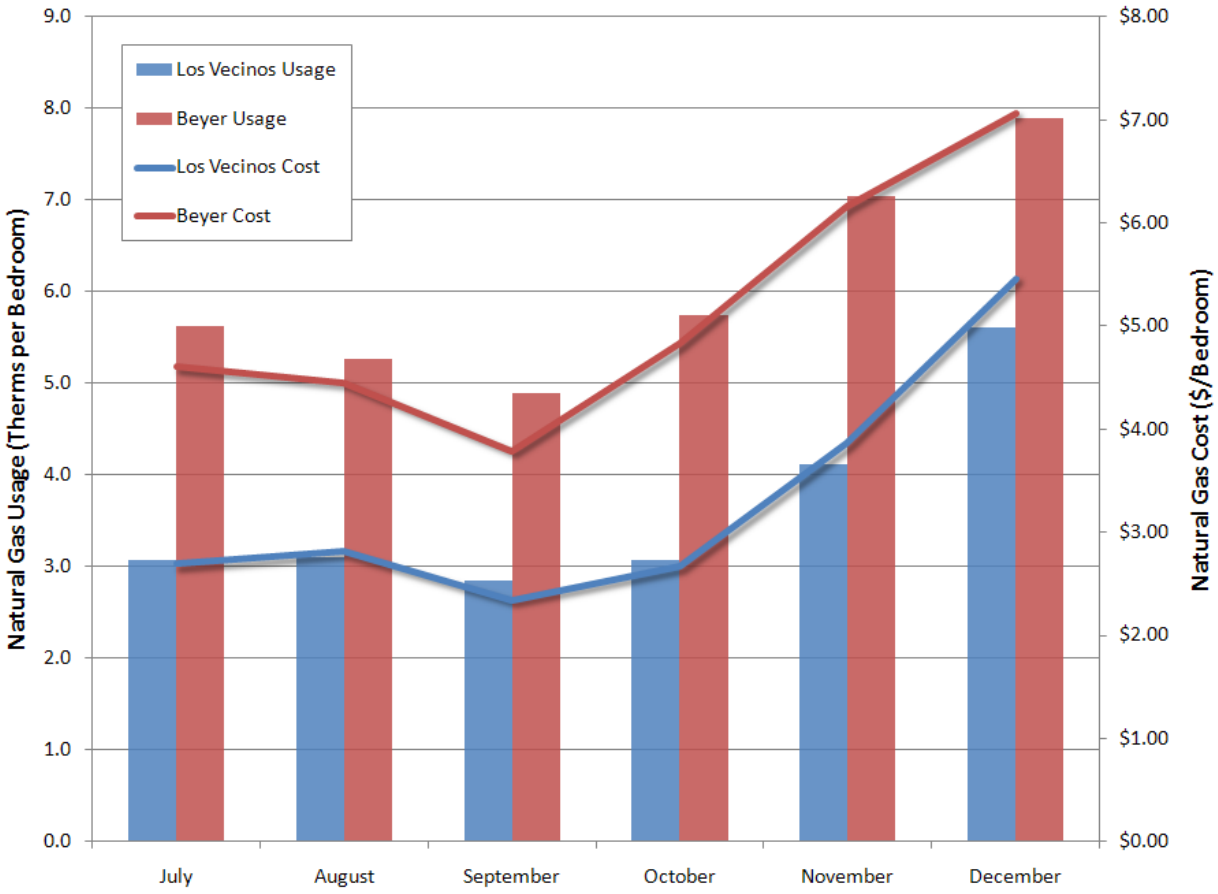


Figure 7. Monthly natural gas Consumption and cost comparison

Source: CTG Energetics

6.1.4. Total Site Energy

The project team analyzed total site energy for the combined performance of electricity and natural gas between Los Vecinos and Beyer. Site energy consumption considers only the direct consumption of fuels on the project site and does not consider primary fuel consumption or losses associated with electric power production, transmission, or natural gas distribution. However, site energy consumption provides a straightforward mechanism for comparing the energy efficiency and utility costs between the two communities.

As shown in Table 10, gross energy consumption at Los Vecinos is 25 percent less than at Beyer. When PV energy production is factored in, Los Vecinos consumes 60 percent less site energy than Beyer. As discussed in previous sections, most of the gross savings are in natural gas use. Total energy costs at Los Vecinos are approximately half compared with Beyer.

Table 10. Total site energy use intensity (EUI) and energy cost intensity (ECI) comparison

Month	Total EUI (kBtu per Bedroom)					Total Average Net ECI ($ per Bedroom)		
	Los Vecinos Net	Los Vecinos Gross	Beyer	Net Percent Less at Los Vecinos	Gross Percent Less at Los Vecinos	Los Vecinos Net	Beyer	Net Percent Less at Los Vecinos
Jul	159	563	810	80%	30%	$4.97	$12.60	61%
Aug	237	601	791	70%	24%	$5.92	$13.10	55%
Sep	247	613	754	67%	19%	$5.90	$12.33	52%
Oct	300	585	824	64%	29%	$5.80	$12.93	55%
Nov	451	692	977	54%	29%	$7.30	$14.95	51%
Dec	671	865	1,061	37%	18%	$9.77	$15.78	38%
Total	2,064	3,920	5,218	60%	25%	$39.20	$81.70	51%[11]

Source: CTG Energetics

The relative normalized costs by fuel type for each community are shown in Figure 8 for the six-month monitoring period. Whereas natural gas costs comprise only 38 percent of total energy costs at Beyer, natural gas costs are 51 percent of the total utility expenditure at Los Vecinos. This result is due to the fact that Los Vecinos's net electricity consumption is much lower than Beyer's.

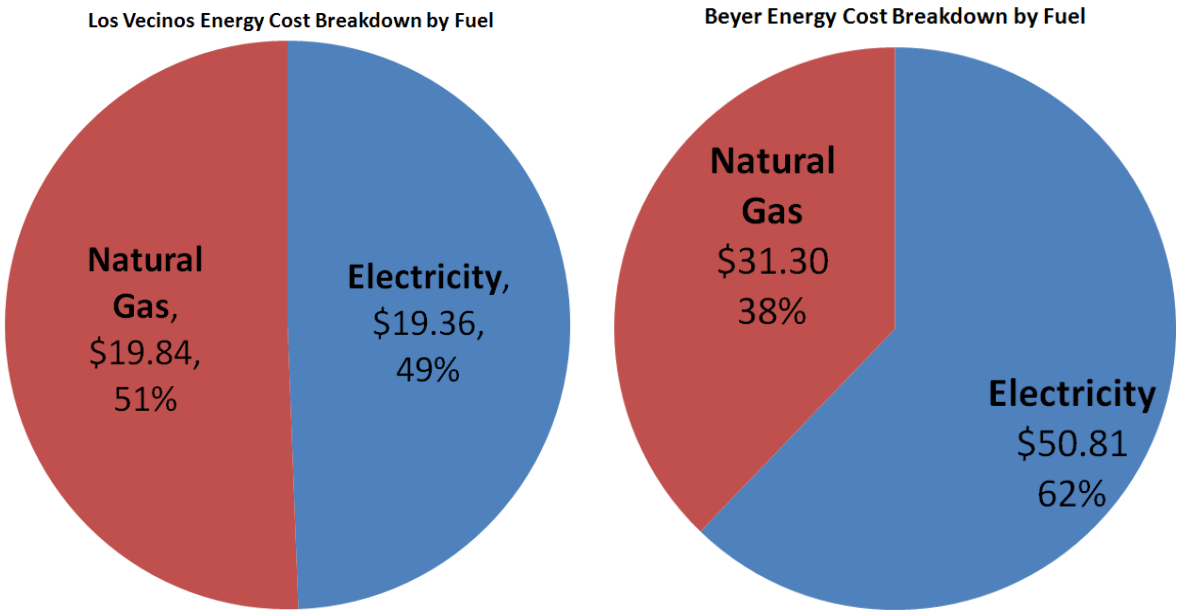


Figure 8. Comparison of net normalized energy cost ($/Bedroom) by fuel for six months

Source: CTG Energetics

11 Total ECI for Los Vecinos includes application of credit earned for electricity generation over the six month study period. Monthly values do not include generation credits.

The monthly trends in total energy costs and consumption for both Los Vecinos and Beyer are shown in Figure 9. As expected, the difference in net energy usage is greatest in the summer when PV production is at a maximum. On the other hand, the monthly reductions in gross consumption at Los Vecinos are much more consistent and are the result of gas savings. The regularity of the differential is mainly the result of two factors: consistent electricity use at both communities throughout the year and a comparable increase in gas usage during the winter months. Again, the similarity in electricity consumption is due to comparable designs at Los Vecinos and the baseline, neither of which includes air conditioning systems that introduce seasonal usage swings.

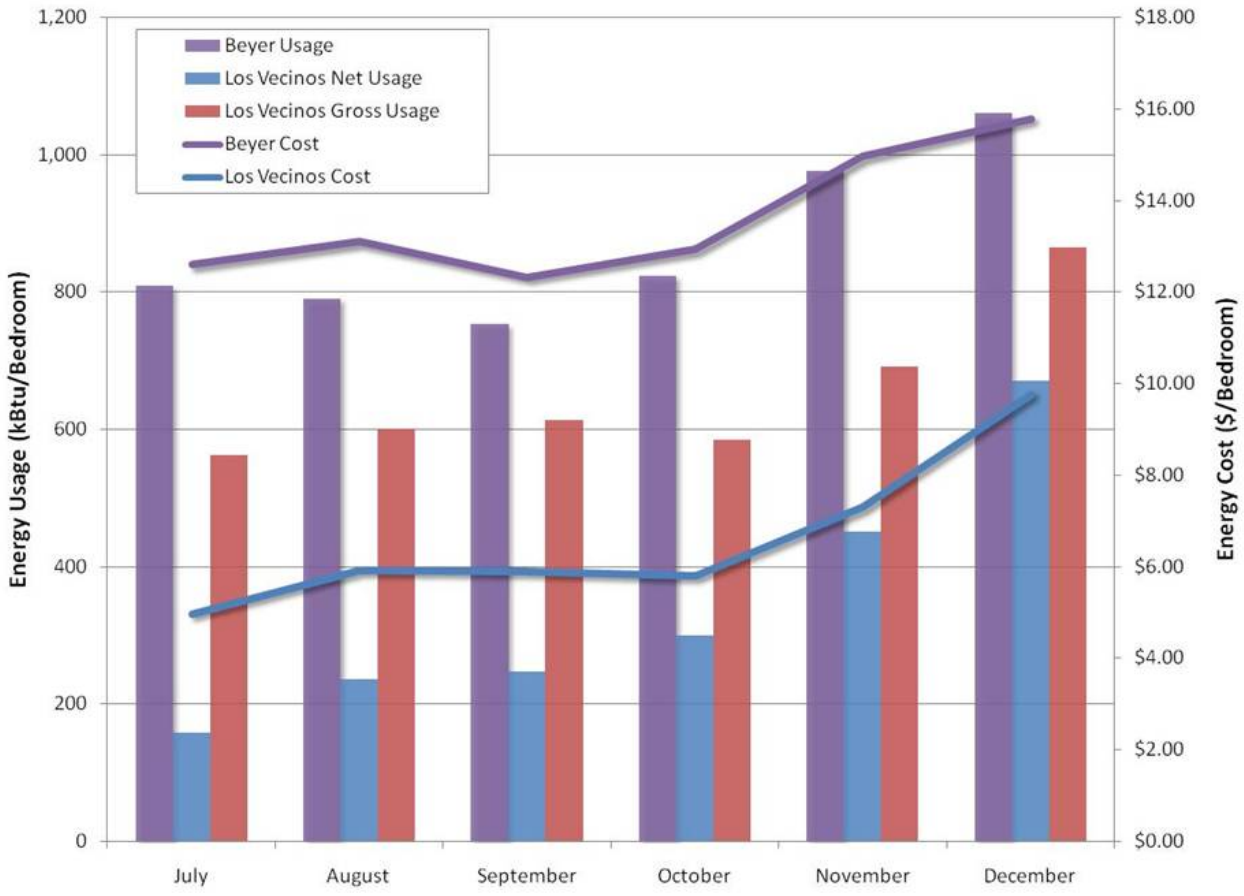


Figure 9. Site energy costs[12] and consumption from July through December 2009

Source: CTG Energetics

12 For this monthly comparison, electricity generation credit has not been applied to billing costs at Los Vecinos.

6.1.5. Gas Utility Rate and Schedule

Residents at both communities are billed for natural gas according to the Residential Natural Gas Service rate schedule (schedule GR), but the ratio of families receiving a low-income discount varies greatly at each community. The 20 percent discounted rate schedule (GR-LI) is provided under the California Alternative Rates for Energy (CARE) Program.

As seen in Table 11, a third of Los Vecinos residents are not enrolled in the CARE program, which amounts to gas bills that are $10 higher every six months than the participating accounts. The enrollment rate at Beyer is well above 90 percent, and assuming that the observed levels of participation are consistent at each facility, costs per therm are 6 percent higher at Los Vecinos than at Beyer.

Table 11. CARE enrollment and cost savings over six months

	Natural Gas	
	Los Vecinos	Beyer
Number of units surveyed	41	32
Number of units enrolled in CARE for gas account	27	32
Percentage enrollment in CARE for gas account	66%	94%
Average ECI discount with CARE ($/Bdrm)	$4.96	$7.82
Average utility cost discount with CARE ($/unit)	$10.21	$19.56
Communitywide effective gas cost rate ($/therm)	$0.91	$0.86

Source: CTG Energetics

6.1.6. Electricity Rate and Schedule

Residents at both communities are billed for electricity according to the Residential Electricity Service rate schedule (schedule DR), but as with natural gas, the ratio of families receiving the CARE low-income discount varies greatly. Over a quarter of surveyed Los Vecinos residents are not enrolled in CARE and are therefore not receiving a 20 percent utility bill discount. As seen in Table 12, Los Vecinos residents enrolled in CARE receive approximately $10 in discounts from their electricity bill every six months.

Table 12. Electricity CARE enrollment and discounts at Los Vecinos and Beyer

	Electricity	
	Los Vecinos	Beyer
Number of Units Surveyed	40	34
Number of units enrolled in CARE for electricity account	29	32
Percentage enrollment in CARE for electricity account	73%	94%
Average ECI discount with CARE ($/Bdrm/six months)	$4.84	$12.70
Average Utility Cost discount with CARE ($/unit/six months)	$9.91	$33.53

Source: CTG Energetics

The CARE program has more stringent requirements for income than either of the communities require for residency; having an apartment at Beyer or Los Vecinos does not necessarily guarantee eligibility for discounted utility rates. Management at Los Vecinos, however, estimates that 85 percent of residents are eligible for the program. Therefore, enrollment rates vary not only because of potentially different income levels at each community, but also because not all eligible Los Vecinos residents have chosen to apply for CARE.

In order to provide a one-to-one comparison, analysis of cost in this study assumes that all residents at both communities receive the discounted electricity rates associated with schedule DR-LI (low income). Using unequal CARE enrollment rates would inaccurately characterize electricity use, and furthermore, would be applicable only for the current mix of residents, as the rate of enrollment in CARE at each community will fluctuate over time.

With the assumption that all residents receive the CARE discount, the project team developed a model to calculate costs for Los Vecinos residents based on their net consumption and the DR-LI rate schedule. The cost model is based on six months worth of billing data from 27 CARE accounts at Beyer.[13] Because observed monthly energy consumption at Los Vecinos rarely exceeds the baseline electricity allowance, the model is designed to focus mainly on Tier 1 rates. Overall, the regression model results in an overall error of less than 3 percent when compared to observed values at Beyer and Los Vecinos.

Net Metering

At the time that the researchers requested utility data, SDG&E had not yet set up about half of Los Vecinos residents as net metering customers. Net metering is necessary in order for residents to receive credit for electricity put onto the grid from PV systems. Once earned, this credit can be used to pay up to 100 percent of total purchased electricity at the end of the billing year.

Since this issue is currently being resolved with SDG&E and in order to provide a fair representation of cost performance, the cost model assumes that all Los Vecinos residents are net metered and are receiving generation credit as appropriate.

Minimum Bill Charges

Minimum bill charges at Los Vecinos have a significant impact on electricity bills. SDG&E customers are charged $0.17 per day for months when electricity purchases do not exceed $0.17 per day. Because most Los Vecinos residents are very low if not negative consumers, the minimum bill charge is often the only cost associated with their electricity accounts. After

13 Complete utility data (i.e. both electricity and gas) from 25 Beyer units are presented throughout most of the study. Electricity data for two additional accounts, however, was provided by the utility and included in the cost model in order to increase the size of the dataset to 27 apartments. The two additional apartments have not been included in any other analysis because their natural gas data was not available.

applying CARE discounts, the six-month minimum charge at Los Vecinos totals $24.75 which accounts for 62 percent of observed electricity charges.

Effective Electricity Cost Rate

Minimum bill charges significantly impact the effective electricity cost rate at Los Vecinos. The effective electricity cost rate is defined simply as the average cost of each unit of electricity ($/kWh) over the six-month monitoring period. Because residents at Los Vecinos incur the minimum bill charge whenever their net usage falls below approximately 37 kWh[14] per month (and even when they are net electricity generators), their effective electricity cost rate is calculated to be $0.19/kWh, almost double the $0.11/kWh observed at Beyer.

To better illustrate the isolated contribution of the minimum bill charge in a CARE/net metering rate situation, Figure 10 summarizes the breakdown of the per apartment electricity cost at each community for the six-month period.

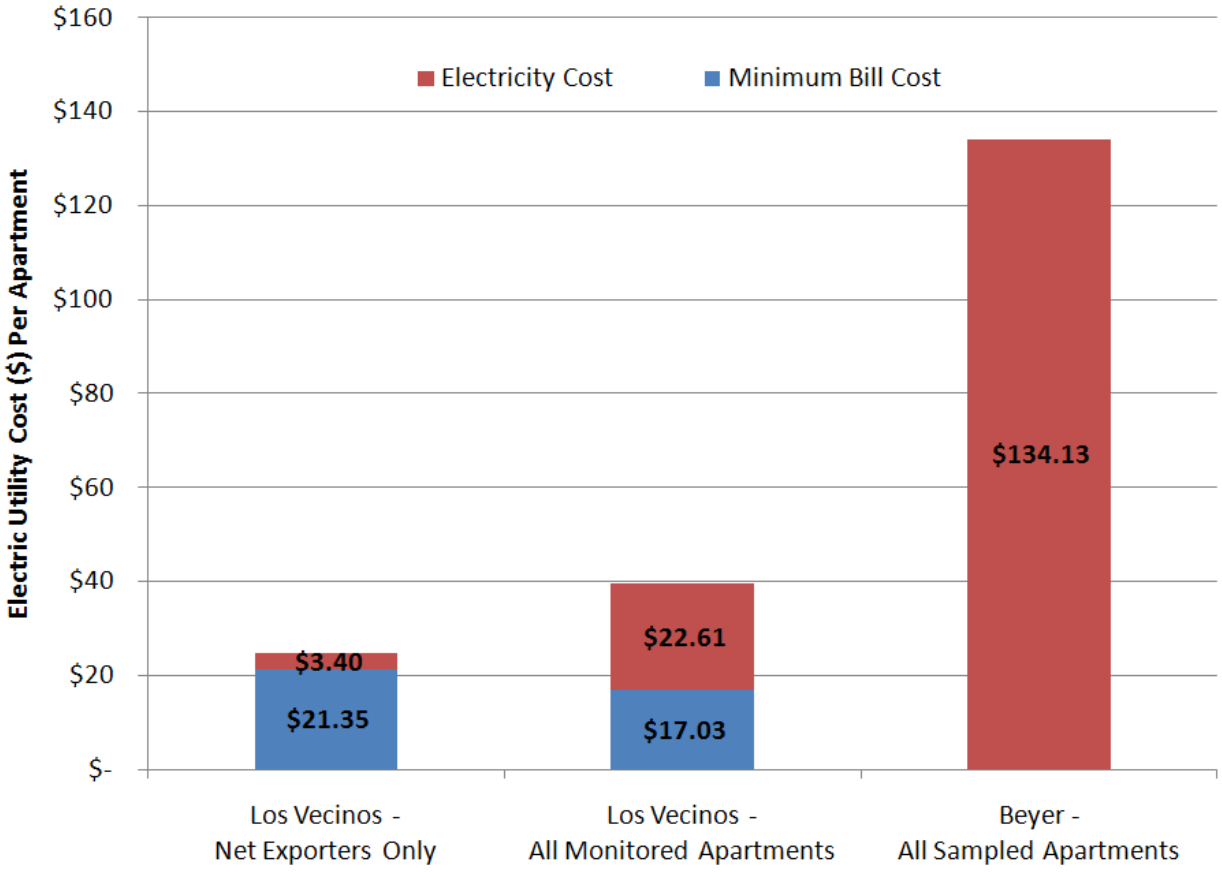


Figure 10. Breakdown of electric utility cost per apartment (six-month monitoring period)

Source: CTG Energetics

14 The 37 kWh associated with minimum bill charge is calculated using Beyer's effective electricity rate of $0.11/kWh.

Although Beyer residents pay higher electricity bills, they use enough electricity every month – more than 37 kWh – to avoid the minimum bill charge. On the other hand, over 40 percent of the electricity cost (i.e., $17.03 of $39.65) for the average Los Vecinos apartment goes toward paying the minimum bill charge. Most of the monitored Los Vecinos residents (16 of 21) are actually net generators for the six-month period, and among this group, the average cost is exactly the amount of the minimum bill charge, $24.75 ($21.35 in minimum charges plus $3.40 in electricity charges), over the six-month period. Consumption is so low, however, that almost 90 percent of this amount goes towards the minimum bill charge. Therefore, as seen in Figure 10, the average Los Vecinos net generating resident pays $24.75 for less than $5 worth of electricity.

The difference in cost associated with minimum bill charges and effective electricity rates represents not only unequal treatment of net electricity exporters and very low net consumers compared to utility customers with no installed renewable energy systems, but also a disincentive for Los Vecinos tenants to reduce their electricity consumption below the 37 kWh monthly amount that is covered by the $4.08[15] minimum monthly charge.

Effect of Net Generation Payments

In 2009, recognizing the perverse incentive of this situation, the California legislature passed and the governor signed into law Assembly Bill 920 (Huffman, Chapter 376, Statues of 2009) directing California utilities to pay net metering customers for excess generation beginning in 2011. The per kWh rate of payment and its method of payment are under negotiation between the California Public Utilities Commission (CPUC) and California electricity providers.

However, since the minimum charge will continue to be billed to net generation customers even when they are being paid for excess generation, there will still be a financial disincentive to true net zero electricity buildings. Figure 10 shows that apartments that are net consumers of between 1 kWh and 37 kWh monthly will still receive a monthly bill for $4.08. Because of these charges, there is no incentive to install enough PV or design enough energy efficiency measures to reach true net zero electricity because there will be a $4.08 charge for any net consumption above 0 kWh/month.

Meanwhile, if Los Vecinos customers were to receive retail CARE rate cash payments for excess generation,[16] they would have to be 37 kWh net exporters each month in order to completely offset, in cash terms, their minimum charge. As seen in Figure 11, for Los Vecinos residents who are already net exporters, this cash payment would exceed their electricity bill by over $12. As a

15 The $4.08 monthly minimum bill charge is based on an average month length of 30 days, daily minimum charge of $0.17, and overall CARE discount of 20%.

16 That customers will receive retail rates is optimistic. In its March 15, 2010 filing for a net generation compensation rate, SDG&E proposed paying customers approximately 5.56 cents/kWh for net kWh exported back to the grid on an annual basis. See Prepared Direct Testimony of Lisa C. Davidson – Application of San Diego Gas & Electric Company (U 902 E) Proposing a Net Surplus Compensation Rate Pursuant to Assembly Bill 920, A.10-03-XXX. Filed with the California Public Utilities Commission March 15, 2010.

group, however, even though the monitored Los Vecinos apartments were net exporters over the six-month period, they would need additional PV capacity in order to truly zero out each resident's electricity bill. Specifically, as seen in Figure 11, the average Los Vecinos resident accrued $28.43 in unused generation credit,[17] but hypothetically, if this credit was converted into a cash payment, their cost would still be $11.22 for the six-month period. Given average PV performance, therefore, each apartment would require an additional 0.13 kW of PV capacity in order to truly zero out the resident's electricity bill.

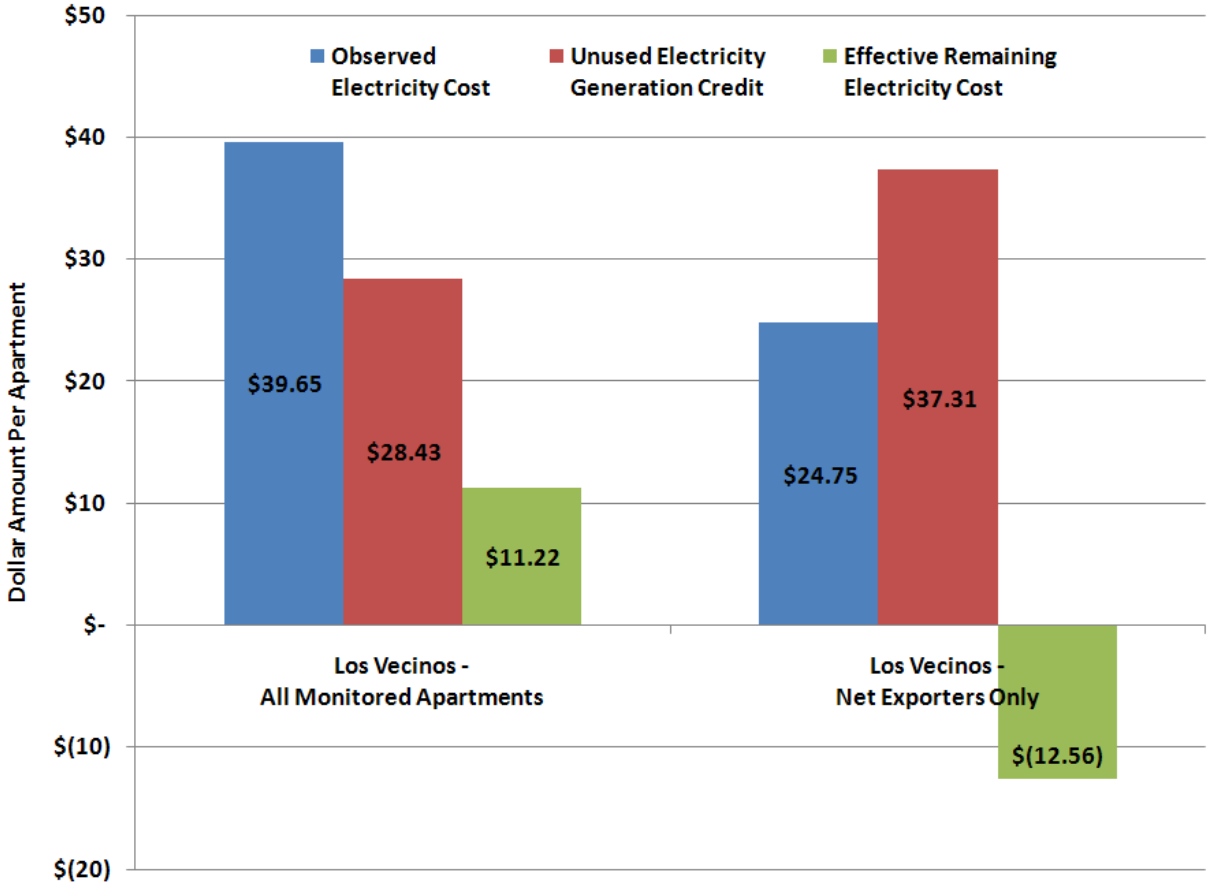


Figure 11. Effective remaining electricity cost assuming retail payment for electricity generation

Source: CTG Energetics

17 Generation credit is a calculated value based on retail CARE rates. The unused value refers to credit that was earned through generation but not currently applied to electricity bills or paid directly to customers.

Further analysis using non-CARE rates and using the ultimate net generation rate approved by the CPUC is necessary to determine how to remove financial disincentives to conservation or renewable energy system installation.

6.2. Peak Electrical Demand Evaluation

6.2.1. ZENH Summer Peak Demand Performance

The ZENH program established that projects should have an average summer peak demand of less than 1 kW per apartment. The summer peak demand is defined as the per apartment power draw averaged over the two hours before and two hours after the moment of utility's maximum power draw during the hottest month of the year.

For the annual monitoring period, August 2009 is the hottest month (i.e., highest average temperature), and the highest power draw occurred on August 28, 2009. As reported by SDG&E, the highest power draw on this day occurred at 4:00 PM. Therefore, as seen in Figure 12, calculation of Los Vecinos' summer peak demand spans 2:00 PM to 6:00 PM and results in a value of -0.30 kW per apartment. This negative value is well below the ZENH goal of 1 kW per apartment and also indicates that Los Vecinos apartments were exporting energy back to the grid at the time the system was most stressed.

Note that demand at the Beyer community is not only relatively constant throughout the day, but that the summer peak demand (0.35 kW) also meets the ZENH goal. These results highlight the impact of air conditioning, or the lack thereof, on peak demand performance.

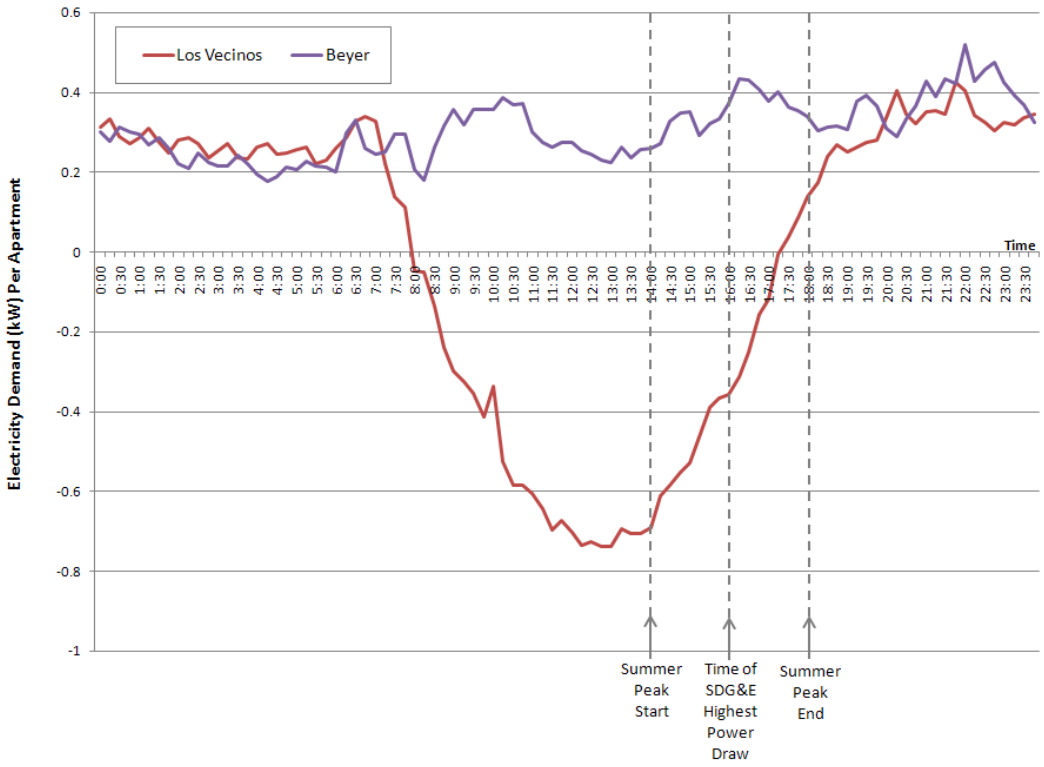


Figure 12. Electricity demand of Los Vecinos and Beyer apartments on the day of the SDG&E summer demand peak: August 28th, 2009

Source: CTG Energetics

6.2.2. Monthly Peak Demand

Comparing demand of the communities at the time of the monthly demand peaks provides valuable insight into demand performance throughout the year. For this purpose, monthly demand peak is defined as the time during each month when the system demand is at its highest (i.e., most stressed). The demand per apartment at both communities can then be determined at these monthly peak demand times for each grid.

As shown in Figure 13, Los Vecinos is a net exporter of electricity at the time of the monthly demand peaks for four of the hottest months of the monitoring period. Furthermore, the highest per apartment demand at Los Vecinos at the time of any SDG&E monthly demand peak is just over 0.4 kW.

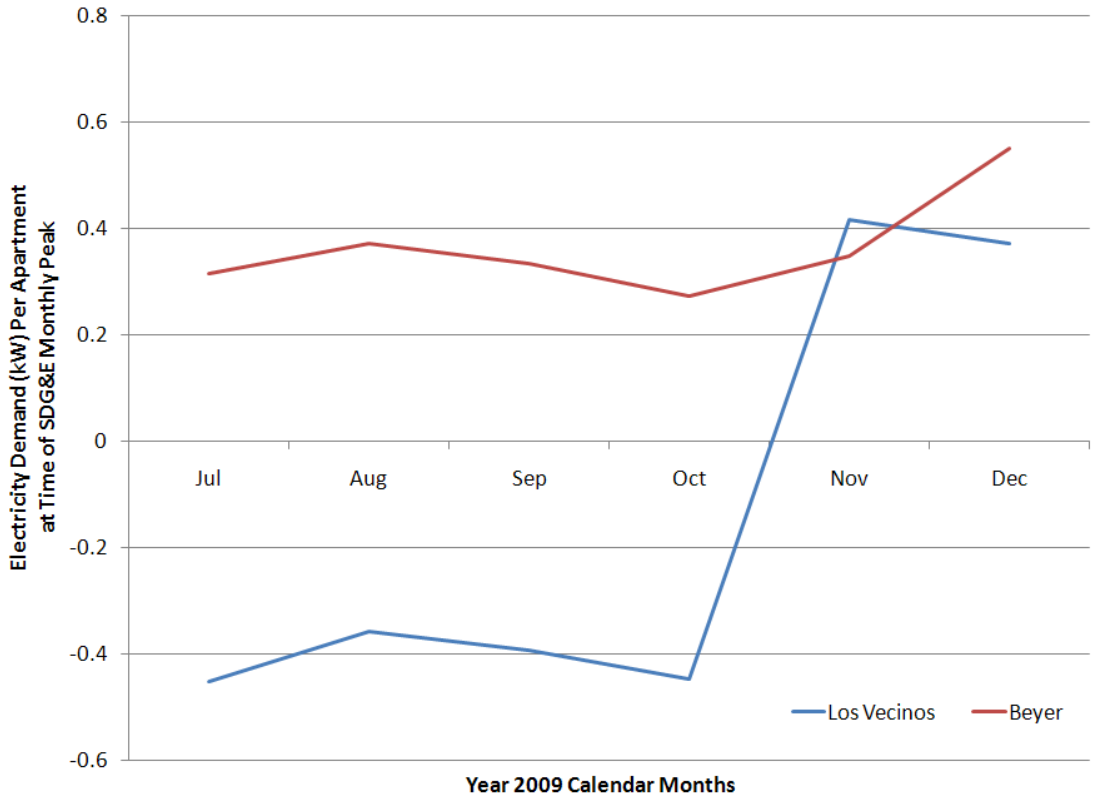


Figure 13. Electricity demand of Los Vecinos and Beyer at the time of the monthly SDG&E demand peaks[18]

Source: CTG Energetics

18 Data correspond with calendar month, not billing cycle. SDG&E provided the time of the monthly peak demand; this time represents the single moment of the highest load experienced by the SDG&E grid during each calendar month. The Los Vecinos and Beyer peak demands were then evaluated at this moment in time.

Similarly, as shown in Figure 14, the Los Vecinos apartments are also net exporters of electricity at the time of the California ISO monthly demand peaks for half of the monitoring period, from July to September.

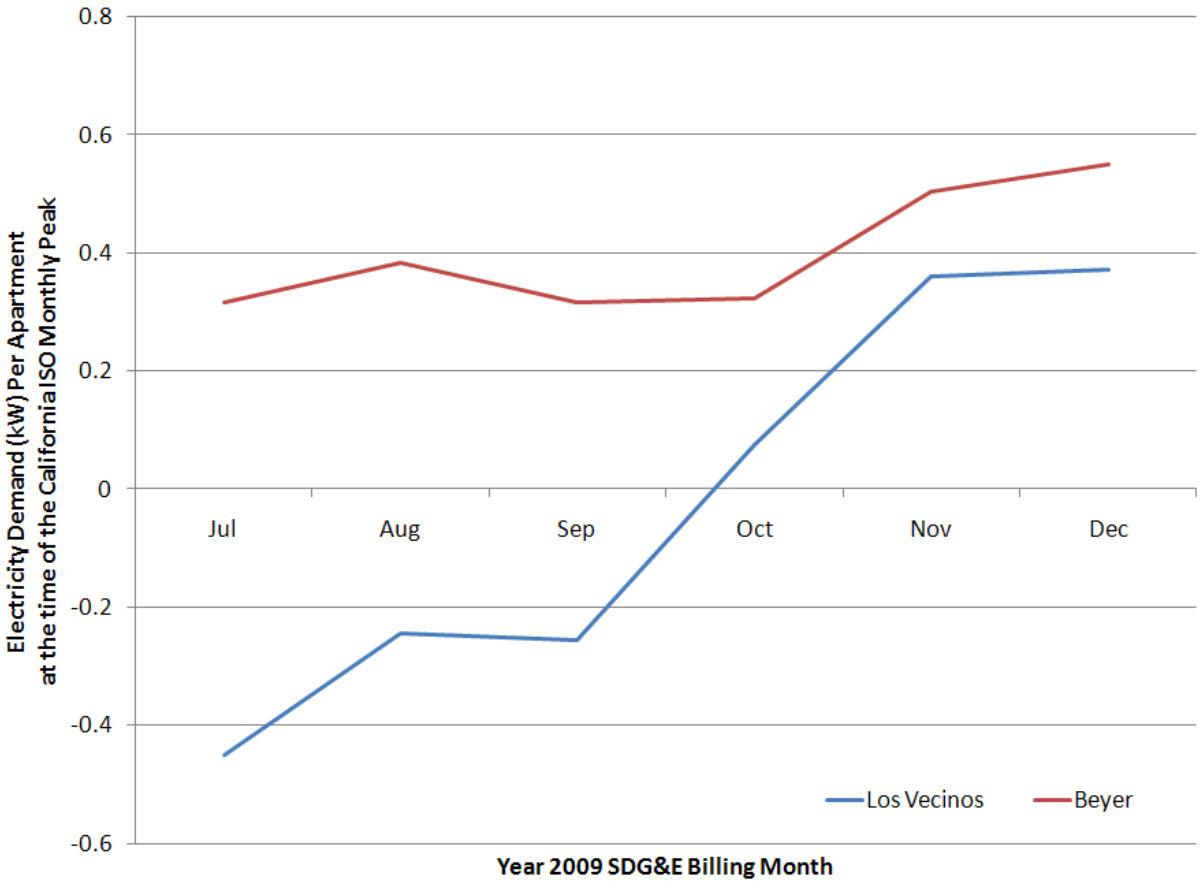


Figure 14. Electricity demand of Los Vecinos and Beyer at the time of the monthly California ISO demand peaks[19]

Source: CTG Energetics

[19] Data shown are for the billing cycle month, which does not correspond directly to the calendar month. The time of the California ISO monthly peak demand was determined from publicly available data published on the California ISO OASIS website (http://oasis.caiso.com); this time represents the single moment in time of the highest load experienced by the California electricity grid during the billing cycle for each month. The Los Vecinos and Beyer peak demands were then evaluated at this moment in time.

7.0 Conclusions and Recommendations

7.1. ZENH Goal Performance

For the July through December 2009 monitoring period analyzed in this report, Los Vecinos met the Zero Energy New Homes (ZENH) goal for summer peak demand per apartment to be below 1 kW. In fact, the 21 monitored Los Vecinos apartments were net exporters to the grid during the SDG&E peak demand period for the three hottest months. Moreover, at the time of the six-month system peak in August 2009, the Los Vecinos apartments were exporting energy *back to the grid*. Based on these data, the design and operation of the Los Vecinos ZENH community reduce grid congestion during the most critical peak demand periods of the year.

Overall, Los Vecinos did not meet the ZENH 70 percent electricity cost reduction goal when compared with Beyer and normalized per bedroom. It met the goal on a per-apartment basis, mainly because Los Vecinos has a significant number of one-bedroom apartments while Beyer has none. The main difference in electricity costs is due to minimum bill charges that Los Vecinos residents pay even when they are net electricity producers.

7.2. Comparison With Modeled Performance

Because the community was designed and built to exceed Title 24 2005 standards by 43 percent, the ZENH goal of a 25 percent reduction in time-dependent valuation energy use was met.

The project team undertook modeling outside of the Title 24 compliance software in order to estimate loads not included in standard compliance energy simulation. The data suggest that both observed gross and net consumptions are significantly lower than expected. This difference is largely due to underestimating PV performance and overestimating loads that are not included in T24 compliance modeling.

7.3. Total Site Energy Use and Cost Performance

Although net electricity costs are 62 percent lower at Los Vecinos when compared with Beyer, total energy costs, including natural gas, are lower by 52 percent on a normalized basis. One cause of this outcome is that less Los Vecinos residents are enrolled in the low income utility discount program (CARE).

Also, the tankless hot water heating systems at Los Vecinos appear to use significantly less natural gas. This results in 25 percent lower gross energy consumption at Los Vecinos even when gross electricity consumption is greater than at Beyer.

7.4. Design Implications for ZENH

There are numerous important lessons from Los Vecinos that can inform future ZENH projects. While trying to achieve zero net electricity consumption, the electrical devices not included in Title 24 compliance energy simulations has a significant impact on overall performance and necessary PV system size. The utility billing rate structure also has a significant impact on ZENH performance.

The project team observed up to a 600 percent difference in the gross electricity consumption among apartments at Los Vecinos. This significant variation of gross electricity consumption suggests that occupant behavior is one factor that needs to be considered when developing, designing, and operating zero energy homes.

To truly achieve net zero energy performance, projects will have to use either electric-only utilities (no natural gas) or on-site solar thermal systems to assist in domestic water and space heating. However, in future ZENH apartment configurations, there may be competition for roof space to deploy both solar photovoltaics for electricity production and solar thermal panels to heat water.

7.5. Recommendations

A number of key recommendations can be drawn from the conclusions:

- Further research is needed to understand the impact of utility billing structures and other strategies for influencing occupant behavior in order to cost-effectively achieve ZENH program goals.
- More performance data are needed over a longer monitoring window to substantiate the utility grid peak demand implications of ZENH projects. Extended performance monitoring may facilitate a re-evaluation of current incentive structures for solar PV and ZENH projects based on their contribution to local grid congestion reduction.
- More research is needed to understand optimized net zero energy designs for affordable and multi-family housing that consider total site energy consumption, including both electricity and natural gas, and to understand in particular limitations to achieving zero net energy based on availability of roof or other space for solar technologies (which can be affected by building form and height and density of living units).
- Communication among property management, the utility company, and solar installers should be streamlined in order to ensure that PV installations, net metering benefits, and low income discounts are set up correctly for projects with multiple net metering accounts.

Appendix A

Monitoring Equipment Information

Power Monitoring Equipment

The power meter used on this project was the Dent Instruments ElitePro™ Recording Poly Phase Power meter. The ElitePro™ meter has the capability to monitor four current channels and four voltage channels (allowing two split-phase residential circuits to be monitored simultaneously with one meter) and can record in user-defined intervals ranging from 3 seconds to 24 hours. The meter is small and lightweight (3.2" x 5.9" x 2.4" and 12oz), has a built-in battery with a lifetime of 3 years at 1-minute sampling intervals and can be purchased with built-in Ethernet connectivity and remote download capability. The following table shows the specifications of the Dent ElitePro™ power meter.

Table 13. Specifications of the Dent ElitePro power meter

Power	Volts, Amps, Watts, Volt-Amps, Power Factor, Volt-Amps-Reactive
Measurements	True RMS
Frequency	50 or 60 Hz
Accuracy	<1% or reading, exclusive of sensor accuracy
Baud Rate (bps)	Direct: Up to 57,500 Modem: Up to 14,400
Memory	128kB (25,000 readings) or 512kB (100,000 readings)
Resolution	Better than 0.1% FS for all parameters; 12 bit A/D (1 part in 4,096)
Sampling Frequency	7.68 kHz (128 points per waveform)
Recording Intervals	Seconds: 3, 15, 30 Minutes: 1, 2, 5, 10, 15, 20, 30 Hours: 1, 12, 24
Real Time Clock	Crystal Controlled, True Calendar, 20 ppm Accuracy (<1 min/month)
Battery Life	3 Years @ 1 Minute Sampling, with LED indicator of low battery
Operating Temperature	-7° to 60°C (20° to 140°F)
Operating Humidity	5% to 96% non-condensing
Dimensions	80mm x 150mm x 60mm (3.2" x 5.9" x 2.4")
Weight	340 grams (12 ounces)
** Only available with 512kB Memory and includes Hanging/Mounting Bracket	

Source: CTG Energetics

The current transformer (CTs) used with the power meters were small split-core type with a 0-50A range (Magnelab Split-Core AC Current Transformer PN: T-MAG-SCT-050). The CTs are approximately 3″x 3″ with a 0.75″ opening; accuracy is within +/- 1% between 10% - 100% of rated range.

Figure 15. A photo of the Dent ElitePro

Source: CTG Energetics

Figure 16. The Dent ElitePro connected to network switches

Source: CTG Energetics

The Dent power meters were connected to network switches, which were run to a router and an onsite computer (i.e., one router and computer at each site). Each Dent power meter was given a unique IP address and the local PC was programmed to call out to the power meters nightly to retrieve the apartment power consumption data.

Database Storage

Because non-trivial data loss occurred during a previous Global Green study (the Solara community in Poway, California), the data covering Los Vecinos and Beyer was automatically downloaded daily and stored in an off-site database. Accompanying database routines greatly simplified not only the collection of data, but more importantly, the identification of erroneous or lost data. In general, the database allowed for the automated execution of the following processes.

- Daily backup and downloading of data from on-site computers/loggers
- Identification of data errors
- Data correction based on user defined algorithm
- Data collection into usable format

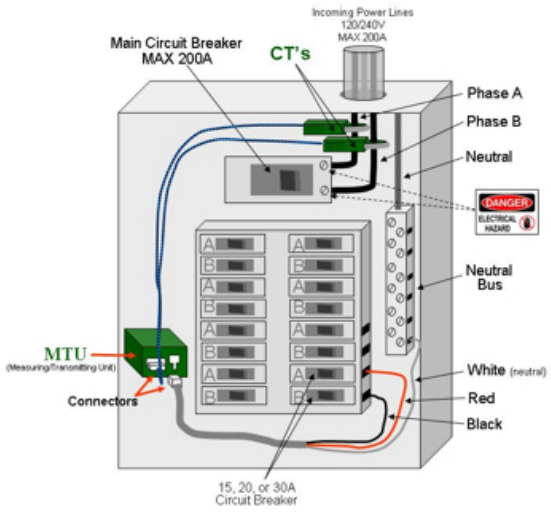
The Energy Detective

The Energy Detective (model TED 1001) is capable of monitoring and displaying the following information. This information is reported on a display unit that is the size of a small alarm clock and can be plugged into a standard electrical outlet.

- Current energy demand in kilowatts (kW).
- Current energy cost in dollars and cents per hour ($/hr).
- Energy consumed so far today in kilowatt-hours (kWh).
- Energy cost so far today in dollars and cents ($).
- Energy consumed so far this billing cycle in kWh.
- Energy cost so far this billing cycle in $.
- Projected energy use for current billing cycle in kWh.
- Projected energy cost for current billing cycle in $.
- Peak electrical demand so far this billing cycle in kW.
- Peak cost so far this billing cycle in $/hr
- Current voltage in Volts (V)
- Minimum voltage this billing cycle in Volts (V)
- Maximum voltage this billing cycle in Volts (V)
- Current Energy Rate (Tariff) in dollars and cents per kilowatt hour $/kWh
- Current Date & Time
- Alarms for cost and usage thresholds
- Historical Data for 13 months

The following figure represents the typical installation of a TED's voltage leads, current transformers, and measuring/transmitting unit in a residential breaker panel.

Figure 17. Typical installation of a TED



Source: CTG Energeti

Attachment I

Project Climate Zone Data

California Climate Zone 7

Reference City:	San Diego
Latitude:	32.73 N
Longitude:	117.17 W
Elevation:	10 ft

Basic Climate Conditions

	(F)
Summer Temperature Range	14
Record High Temperature (1963)	111
Record Low Temperature (1949)	29

Design Day Data

Winter	99%	42		
	97.5%	44		
Summer				
	1%:	83	MCWB	69
	2.5%:	80	MCWB	69

Climatic Design Priorities

Winter:	Insulate
	Reduce Infiltration
	Passive Solar
Summer:	Shade
	Allow natural ventilation
	Distribute Thermal Mass

Title 24 Requirements

Package	*C*	*D*
Ceiling Insulation	R38	R30
Wood Frame Walls	R21	R13
Glazing U-Value	0.38	0.67
Maximum Total Area	14%	20%

Climate

Climate Zone 7 is the southernmost coastal region of California. The warm ocean water and latitude make this climate very mild. The temperature of the ocean water affects the air temperature over it, and this in turn moderates temperatures over the coastal strip.

The ocean influences the weather most of the time, however the wind changes sometimes, bringing in the hot and extremely drying Santa Ana winds. The weather in the summer is warm and comfortable, and hot enough that cooling is necessary on some days.

	Oceanside	*Chula Vista*	*San Diego*	*La Mesa*
HDD	2009	1321	1256	1400
CDD	505	862	984	1110

HDD = Heating Degree Days (base 65F)
CDD = Cooling Degree Days

However, daily high fogs naturally cool the area at night. The winters are cool and heating is necessary sometimes. The weather and comfort standards in this region are in concurrence as shown by the low consumption of energy use.

[1]http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zone_07.pdf

Attachment II

Equipment Information for Los Vecinos PV Installations

SP Series Solar Module Model SP200

Standard Test Conditions—(Irradiance of 1000 W/m², AM1.5 Spectrum and Cell Temperature of 25°)

Electrical Characteristics

Model Number	SP200
Cell Type	Multi-Crystalline Si
No. of Cells	54
Maximum Power	200 W
Maximum Power Voltage	25.41 V
Maximum Power Current	7.87 A
Open Circuit Voltage	32.3 V
Short Circuit Current	8.40 A
Maximum System Voltage	600 V (UL)/ 1000 V (IEC)
Fuse Rating	15 A
Power Tolerance	+/- 3%
Temp. Coefficient of Isc	0.120%/°C
Temp. Coefficient of Voc	-0.349%/°C

Physical Characteristics

Model Number	SP200
Length	58.07"/1475 mm
Width	39.21"/996 mm
Height	1.81"/46 mm
Weight	37.8 lb./17.2 kg

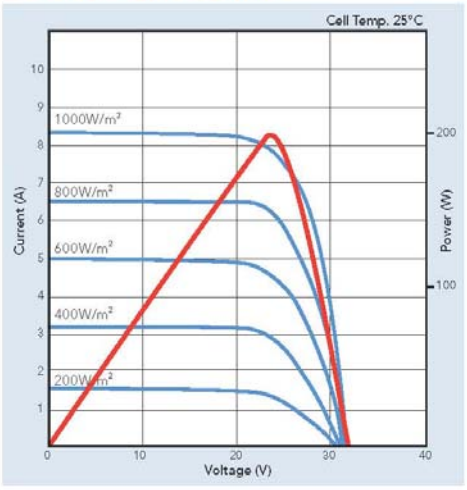
Contact Information:

1-800-548-8767

Corporate Headquarters
1115 Orlando Avenue
Roseville, CA 95661-5247
Phone: 916.745.0900
Fax: 916.745.0999

www.solarpowerinc.net

IV– Characteristics of PV Module SP200F Series at Various Irradiance Levels



SOLAR POWER INC.
Energy for Life™

SP Series Solar Module Model SP200

SP Series SP200

- *Maximizes total system power output*
- *Achieves higher output with fewer modules*
- *IEC certified and UL listed*

The following features are standard on every SP Series module:

- *One of the highest energy output classes in the industry*
- *Bypass diodes to minimize power drop caused by shade*
- *Innovative cable connectors make installation easy*
- *25-year limited warranty*

Manufactured, assembled and tested in our own ISO 9001 facility, SP Series solar modules feature one of the highest grade photovoltaic (PV) cells available. Cells are subjected to rigorous testing to verify performance and integrity before being assembled into a module. Our SP200 modules are designed with 6" silicon cells to optimize performance and to maximize use of today's limited silicon supply. Every SP Series solar module is UL listed; conforms to IEC 61215/61730-1/61730-2; and carries a 25-year limited warranty.

The SP200 has been engineered to achieve higher output with fewer modules in a single array. Like the entire SP Series line of solar modules, the SP200 carries one of the highest energy output classes in the industry and has unique standard features that ensure long life and consistent performance. Bypass diodes are standard and serve to minimize power drop caused by shading, ensuring consistently higher energy yields and superior year-round performance.

Built to Last

SP Series solar modules are designed to withstand harsh environments and extreme operating conditions. All models are tested to ensure continuous performance under conditions they will probably never encounter:

- Repetitive cycling between -40°F and 194°F at 85% relative humidity
- Simulated impact of 2" hail at 72 mph.
- Damp heat tested for 240 hours with exposure to 185°F and 85% relative humidity
- IEC certified
- UL listed

SOLAR POWER INC.
Energy for Life™

proven history, sustainable future

Solectria Renewables designs and manufactures power electronics for renewable power generation systems. Feature-packed and highly integrated, the products lead the industry in installation ease and total value. At the heart of Solectria's products are its reliable and efficient core inverters, which have been proven over the past 20 years in the extremely harsh environment of truck, bus and military transportation applications. Solectria Renewables is run by the renowned MIT engineers who founded the Solectria brand in 1989. With a customer-focused team, high quality suppliers and a best practices manufacturing process, Solectria is committed to your success.

SOLECTRIA RENEWABLES

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USA

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Ph: 562.608.8913 (CA)
Fax: 978.683.9702
inverters@solren.com
www.solren.com

Background: 3.1 kW solar array using PVI 2500 inverter. Right: Happy PVI 1800 customer, Harvest Solar.
Left: Lightweight for easy installation. Center: 30 kW condo installation with 11 PVI 2500 integrated panel assemblies by CSG.

SOLECTRIA RENEWABLES

Grid-Tied PV Inverters

PVI 1800 PVI 2500

a breakthrough in price and quality

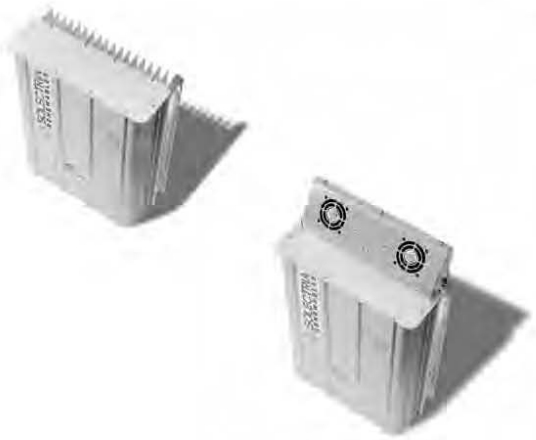
TÜV

Solectria introduces the PVI 1800/PVI 2500 inverter:
exceptional quality and efficiency at an extraordinary price.

Product Information

INVERTER SPECIFICATIONS

	PVI 1800	PVI 2500
Input		
Continuous Power	1950 W	2700 W
Recommended Max. PV Array Power, STC rating	2200 Wp DC	3200 Wp DC
MPPT Voltage Range	125V DC – 350V DC	125V DC – 350V DC
Maximum Voltage (OCV-Cold)	400V DC	400 V DC
Maximum DC Current	11 ADC	15 ADC
Output		
Continuous Power	1800W	2500W
Nominal Voltage	240/208V AC	240/208V AC
Voltage Range (–12%/+10%)	240/208V AC	240/208V AC
Nominal Current	7.5 /8.7A	10.4/12A
Frequency	60 Hz, ±1%	60 Hz, ±1%
Power Factor	Unity	Unity
Distortion Factor (THD)	<4%	<4%
Maximum Efficiency	94.5%	94.5%
General Information		
DC and AC Connections	Pre-wired	Pre-wired
Housing Material	Aluminum	Aluminum
Convection Cooling	Yes	Yes/Fan
Weight	34.2 lbs / 15.5 kg	36.4 lbs / 16.5 kg
Ambient Temperature (full power)	-13°F to +130°F	-13°F to +130°F
Relative Humidity	95%	95%
Enclosure	NEMA 4 / IP 65	NEMA 4 / IP 65
Length	18.5 inches (470 mm)	23.6 inches (600 mm)
Width	13.1 inches (333 mm)	13.1 inches (333 mm)
Height	5.63 inches (143 mm)	5.63 inches (143 mm)
Communication		
Display and Indicators	LCD display & LEDs for status indication, error messages, instantaneous & historical data.	
External Communication	RS 232 or 485 (standard equipment-automatic recognition of RS 232 or 485)	
Data Monitoring	Optional SolrenView or Fat Spaniel, also compatible with others	
Standards		
	Listed to UL 1741, IEEE std 1547	
	FCC part 15 A&B	FCC part 15 A&B
	ANSI C62.41 C1 & C3	ANSI C62.41 C1 & C3
Warranty		
	Standard 5 years Optional extended warranties to 10 & 15 years	



INTEGRATED PANEL ASSEMBLIES

OVERVIEW

The Integrated Panel Assemblies are options for the PVI 1800 or PVI 2500 inverters. They can be used with inverters set to 240VAC or 208VAC. These panels make installing a PV system even faster and easier. The complete panel with inverter weighs only 65 lb (29.5 kg) and can ship UPS. The standard version includes visible-blade AC and DC disconnects, an optional revenue grade, factory sealed, reconditioned kWh meter all mounted on an aluminum panel using stainless steel hardware. The design compliments the sleek, low profile inverters providing a clean, compact installation whether indoors or outdoors.

APPLICATIONS

- *1-3 kW single panel residential or commercial installations.*
- *Multiple 1-3 kW residential or commercial separately metered systems in town houses, condos or apartments.*
- *Two & three-inverter panels available for 4-9 kW Systems (3.6-7.5 kW AC). Multiple paralleled panels are used without kWh meters and the panels are combined to go through a single kWh meter.*
- *Versions available with various parts omitted, added or substituted to meet any state, municipal or utility requirement.*

PANEL CONFIGURATIONS

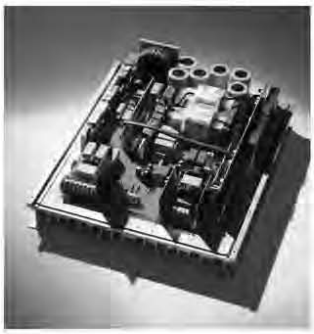
Single-Inverter panels
33" wide (65 lbs). *(All Panels are 26.8" high)*

Double-Inverter panel
with DC disconnect, optional AC breaker panel and optional kWh meter 45" wide (104 lbs).

Triple-Inverter panel
with DC disconnect but no meter/socket or AC disconnect: 48.5" wide (127 lbs).

PVI 1800 PVI 2500

Grid-Tied PV Inverters



RELIABILITY

The PVI 1800/PVI 2500 provides industry leading reliability. One look at the automated production and PCB assembly inside the inverter shows its industrial quality. Rigorously designed and tested for the harshest conditions, the PVI 1800/PVI 2500 proves to be consistently reliable.

EASY TO INSTALL

The PVI 1800/PVI 2500 can be installed easily and quickly, both indoors and outdoors. With a weight of 35 lbs [16kg] (compared to and average 70 lb [32kg] for a typical inverter) the PVI 1800/PVI 2500 is very easy to handle. The inverters also include 'pre-wired' AC and DC cables for quick wiring at the jobsite without opening the inverter!

EASY TO OPERATE: PLUG AND PLAY MONITORING

With the PVI 1800/PVI 2500, Solectria Renewables once again confirms its innovative reputation. With LCD display and auto detect RS232/485 as standard equipment, there is true "plug and play" capability. This gives the PVI 1800/PVI 2500 a PC interface with excellent monitoring and data acquisition capability. Free PC software. Optional SolrenView or Fat Spaniel web-based monitoring. Also compatible with Draker & other data monitoring packages.

SAFETY

The PVI 1800/PVI 2500 has been tested to the latest UL 1741 and IEEE std 1547 standards and meets all the requirements. An important selling point of this inverter is the galvanic isolation, which increases both reliability and safety.

HIGH THERMAL PERFORMANCE

All aluminium construction and high efficiency design provides full rated power in ambient temperatures up to 130°F (55°C). No derating will occur!

PVI 1800 and PVI 2500 PV SYSTEM BLOCK DIAGRAM